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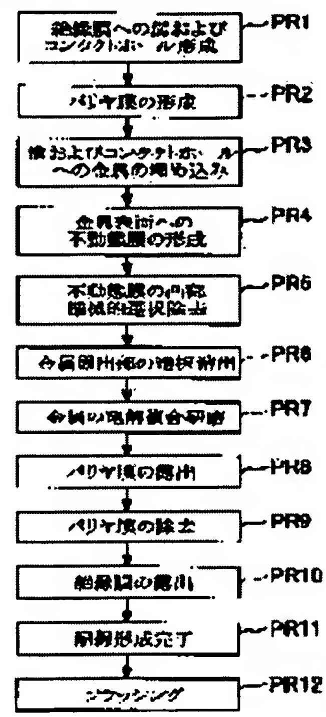
(54) MANUFACTURE OF SEMICONDUCTOR DEVICE, AND METHOD AND DEVICE FOR POLISHING

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a polishing method, a polishing device, and a manufacturing method for a semiconductor device, where occurrence of dishing or erosion is suppressed in a planarizing process for polishing a metal film to constitute wiring of a semiconductor device having a multilayer interconnection structure.

SOLUTION: A process (PR4) for forming a passive state film on the surface of a metal film which prevents electrolytic reaction of the metal, process (PR5) where a protruding passive state film present on the surface of metal film which is generated by filling a wiring channel is selectively removed by mechanical polishing so that the protruding metal film is exposed on the surface, a process (PR6) where the exposed protruding part of the metal film is removed by electrolytic polishing, so that the rough surface of the metal film generated by filling of filling of the wiring channel is planarized, and a process (PR7) where a metal film present on the insulating film of the metal film whose surface is planarized is removed by electrolytic composite polishing, where electrolytic polishing and mechanical polishing are composed to form wiring are provided.



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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the polish equipment and the polish approach of carrying out flattening of the concave convex accompanying the multilayer-interconnection structure of a semiconductor device, and the manufacture approach of a semiconductor device with multilayer-interconnection structure.
[0002]
[Description of the Prior Art] With high integration of a semiconductor device, and a miniaturization, contraction-izing of detailed-izing of wiring and a wiring pitch and multilayering of wiring are progressing, and the importance of the multilayer-interconnection technique in the manufacture process of a semiconductor device is increasing. On the other hand, although aluminum (aluminum) has been conventionally used abundantly as a wiring material of the semiconductor device of multilayer-interconnection structure, in order to control the propagation delay of a signal in the design rule below the latest 0.25-micrometer Ruhr, development of the wiring process which replaced the wiring material with copper (Cu) from aluminum (aluminum) is performed briskly. When Cu is used for wiring, there is a merit that it is compatible in low resistance and high electromigration resistance. In the process which used this Cu for wiring, a metal is embedded at the groove circuit pattern beforehand formed in the interlayer insulation film, for example, and it is CMP (Chemical Mechanical Polishing: chemical machinery polish). DAMASHIN which removes an excessive metal membrane and forms wiring by law (damascene) The wiring process called law is leading. Since etching of wiring becomes unnecessary and the upper interlayer insulation film will also become flat naturally further, this DAMASHIN method has the description that a process can be simplified. furthermore, dual DAMASHIN (dual damascene) which opens not only wiring but a contact hole in an interlayer insulation film as a slot, and embeds wiring and a contact hole with a metal at coincidence -- in law, it becomes reducible [still larger wiring processes].
[0003] Here, an example of the wiring formation process by the above-mentioned dual DAMASHIN method is explained with reference to drawing 32 - drawing 37 . In addition, the case where Cu is used as a wiring material is explained. first, the interlayer insulation film 302 with which the impurity diffusion field which is not illustrated consists of silicon oxide on the substrate 301 which consists of semi-conductors, such as silicon currently formed suitably, as shown in drawing 32 -- for example, the reduced pressure CVD (Chemical Vapour Deposition) -- it forms by law. Subsequently, as shown in drawing 33 , the slot 304 in which wiring of the predetermined pattern electrically connected with the impurity diffusion field of the contact hole 303 and substrate 301 which lead to the impurity diffusion field of a substrate 301 is formed is formed using a well-known photolithography technique and an etching technique. Subsequently, as shown in drawing 34 , the barrier film 305 is formed in the front face of an interlayer insulation film 302 and a contact hole 303, and a slot 304. This barrier film 305 forms ingredients, such as Ta, Ti, TaN, and TiN, by the well-known spatter. The barrier film 305 is formed in order that the ingredient which constitutes wiring may prevent being spread in an interlayer insulation film 302. This is prevented, in order that especially Cu may have a large diffusion coefficient to silicon oxide and a wiring material may tend to oxidize by Cu, case [whose interlayer insulation film 302 is / like silicon oxide].
[0004] Subsequently, on the barrier film 305, as shown in drawing 35 , the Cu film 307 is formed so that the seed Cu film 306 may be formed by predetermined thickness by the well-known spatter, and may be shown subsequently to drawing 36 , and a contact hole 303 and a slot 304 may be embedded by Cu. The Cu film 307 is formed by plating, the CVD method, a spatter, etc. Subsequently, as shown in drawing 37 , flattening of the excessive Cu film 307 and the barrier film 305 on an interlayer insulation film 302 is removed and carried out by the CMP method. Wiring 308 and contact 309 are formed of this. A multilayer interconnection can be formed by repeating the above-mentioned process on wiring 308, and performing it.
[0005]
[Problem(s) to be Solved by the Invention] By the way, in the multilayer-interconnection formation process using the above-mentioned dual DAMASHIN method, in the process which removes the excessive Cu film 307 and the barrier film

305 by the CMP method, since removal engine performance with an interlayer insulation film 302, the Cu film 307, and the barrier film 305 differed, disadvantageous profit of being easy to generate dishing, erosion (web thinning), a recess, etc. existed in wiring 308. When the large wiring 308 of width of face like about 100 micrometers exists in the design rule of 0.18-micrometer Ruhr, dishing is the phenomenon of the center section of the wiring concerned being removed superfluously and cratering it, and as shown in drawing 38 , since the cross section of wiring 308 runs short if this dishing occurs, it causes poor wiring resistance. When comparatively elastic copper and aluminum are used for a wiring material, it is easy to generate this dishing. As shown in drawing 39 , erosion is the phenomenon in which a part with a high pattern consistency by which wiring with a width of face of 1.0 micrometers is formed in the range of 3000 micrometers by 50% of consistency will be removed superfluously, and since the cross section of wiring runs short if erosion occurs, it causes poor wiring resistance. As shown in drawing 40 , wiring 308 becomes low on the boundary of an interlayer insulation film 302 and wiring 308, a recess is the phenomenon which can do a level difference, and since the cross section of wiring runs short also in this case, it causes poor wiring resistance. Furthermore, it is necessary to remove efficiently the Cu film 307 and the barrier film 305, and it is required at the process which removes the excessive Cu film 307 and the barrier film 305 by the CMP method that the polish rate which is the amount of removal per unit time amount should become 500 or more nm/min. If it is necessary to enlarge the processing pressure force over a wafer and the processing pressure force is enlarged in order to earn this polish rate, as shown in drawing 41 , it will be easy to generate Scratch SC and the chemical damage CD on a wiring front face, they will become it, and it will especially be easy to generate with elastic Cu and aluminum. For this reason, when it became the cause of the fault of opening of wiring, short one, and poor wiring resistance and the processing pressure force was enlarged, disadvantageous profit that the yield of the above-mentioned dishing, erosion, and a recess also became large existed.
[0006] In case this invention carries out flattening of the metal membranes which are made in view of the above-mentioned problem, for example, have multilayer-interconnection structure, such as wiring of a semiconductor device, by polish, it can carry out flattening of the initial irregularity easily, and is excellent in the removal effectiveness of an excessive metal membrane, and offers the polish equipment which can control generating of superfluous removal and the polish approach of metal membranes, such as dishing and erosion, and the manufacture approach of a semiconductor device.
[0007]
[Means for Solving the Problem] The abrasive tools which the polish equipment of this invention has a polished surface, and have conductivity, and an abrasive-tools rotation maintenance means to rotate and hold said abrasive tools centering on a predetermined revolving shaft, The rotation maintenance means which holds a ground object and is rotated centering on a predetermined revolving shaft, The migration positioning means which carries out migration positioning of said abrasive tools in the target position of the direction which counters said ground object, A relative-displacement means to make the polished surface-ed of said ground object, and the polished surface of said abrasive tools displaced relatively along a predetermined flat surface, It has an electrolytic-solution supply means to supply the electrolytic solution on the polished surface-ed of said ground object, and an electrolytic current supply means to supply the electrolytic current which makes an anode plate the polished surface-ed of said ground object, and flows from said polished surface-ed to said abrasive tools through said electrolytic solution by using said abrasive tools as cathode.
[0008] Moreover, it has the abrasive tools which have the polished surface which contacts while the polish equipment of this invention rotates all over the polished surface-ed of a ground object. It is polish equipment which is contacted making said polished surface rotate said ground object, and carries out flattening polish. Have an electrolytic-solution supply means to supply the electrolytic solution on said polished surface, and said polished surface is equipped with the anode plate electrode and cathode electrode of said ground object which can be energized to a polished surface-ed. Flattening polish of the polished surface-ed of said ground object is carried out by electrolysis compound polish which compounded electrolytic polishing by said electrolytic solution, and mechanical polishing by said polished surface.
[0009] The polish approach of this invention makes the electrolytic solution intervene, forces the polished surface of conductive abrasive tools, and the front face of the ground object with which the metal membrane was formed in the front face or the inner layer at least, uses said abrasive tools as cathode, and makes the front face of said ground object an anode plate. The electrolytic current which flows from the front face of said ground object through said electrolytic solution to said abrasive tools is supplied. You make it displaced relatively along a predetermined flat surface, rotating both said abrasive tools and said ground object, and flattening of the metal membrane formed in said ground object of the electrolysis compound polish which compounded said electrolytic-solution **** electrolytic polishing and mechanical polishing by said polished surface is carried out.
[0010] Moreover, the process which forms the passive state film which demonstrates the operation which bars the electrolysis reaction of the metal membrane concerned in the front face of a metal membrane on which the polish approach of this invention was formed in the ground object, The process which the electrolytic solution is made to intervene between the polished surface of conductive abrasive tools, and said metal membrane, and forces a polished

surface and a metal membrane concerned, and impresses a predetermined electrical potential difference in between with said abrasive tools and said metal membrane, The polished surface of said abrasive tools and the metal membrane of said ground object are made displaced relatively along a predetermined flat surface. The process which removes alternatively the passive state film on the heights projected to the polished surface of said abrasive tools among said metal membranes by mechanical polishing of said abrasive tools, It has the process which removes the heights of the metal membrane which said passive state film was removed and was exposed to the front face according to the electrolytic-polishing operation by said electrolytic solution, and carries out flattening of said metal membrane.
[0011] The manufacture approach of the semiconductor device of this invention so that the process which forms the slot for wiring for forming wiring in the insulator layer formed on the substrate, and said slot for wiring may be embedded The process which forms the passive state film which demonstrates the operation which bars the electrolysis reaction of the metal membrane concerned in the front face of the process which makes a metal membrane deposit on said insulator layer, and the metal membrane deposited on said insulator layer, The process which mechanical polishing removes [process] alternatively the immobilization film on the heights which exist in the front face of said metal membrane produced by the embedding of said slot for wiring among the passive state film formed in said metal membrane, and exposes the heights of the metal concerned on a front face, Electrolytic polishing removes the heights of said exposed metal membrane, and it has the process which carries out flattening of the irregularity of the front face of said metal membrane produced by the embedding of said slot for wiring.
[0012] moreover, the electrolysis compound polish which compounded electrolytic polishing and mechanical polishing for the excessive metal membrane to which the manufacture approach of the semiconductor device of this invention exists on said insulator layer of the metal membrane to which flattening of said front face was carried out -- it removes and has further the process which forms said wiring.
[0013] By the manufacture approach of the semiconductor device of this invention, the passive state film is formed in the metal membrane which has irregularity in a front face, and the heights of a metal membrane are exposed to a front face by removing the passive state film mechanically. The heights of this metal membrane are alternatively eluted by the electrolytic action by the electrolytic solution by using the remaining passive state film as a mask. Consequently, flattening of the initial irregularity of a metal membrane is carried out. Moreover, in case the metal membrane to which flattening of the initial irregularity was carried out is removed by electrolysis compound polish at high efficiency, for example, wiring is formed, the excessive metal membrane which exists on an insulator layer is removed by high efficiency. If an excessive metal membrane is removed and an insulator layer is exposed, the electrolytic action of the part will stop automatically and the metal membrane embedded in the slot for wiring formed in the insulator layer will not be removed superfluously.
[0014]
[Embodiment of the Invention] Hereafter, the gestalt of operation of this invention is explained with reference to a drawing.
The block diagram 1 of polish equipment is drawing showing the configuration of the polish equipment concerning 1 operation gestalt of this invention. Drawing 2 is the important section enlarged drawing of the processing head section of the polish equipment shown in drawing 1 . The polish equipment 1 shown in drawing 1 is equipped with the processing head section 2, the electrolysis power source 61, the controller 55 that has the function which controls the polish equipment 1 whole, the slurry feeder 71, and the electrolytic-solution feeder 81. In addition, although not illustrated, polish equipment 1 is installed in a clean room, and the taking-out close port which carries out taking-out close [of the wafer cassette which held the wafer as a ground object] is prepared in the clean room concerned. Furthermore, the wafer carrier robot which delivers a wafer between the wafer cassettes and the polish equipment 1 which were carried in in the clean room through this taking-out close port is installed between a taking-out close port and polish equipment 1.
[0015] The processing head section 2 holds abrasive tools 3, makes it rotate, and is equipped with the abrasive-tools attaching part 11 holding abrasive tools 3, the Z-axis positioning device section 31 which positions the abrasive-tools attaching part 11 to the target position of Z shaft orientations, and the X-axis migration device section 41 which is made to hold and rotate the wafer W as a ground object, and moves to X shaft orientations. In addition, the abrasive-tools attaching part 11 supports one example of the abrasive-tools rotation maintenance means of this invention, the X-axis migration device section 41 supports one example of the rotation maintenance means of this invention, and a relative-displacement means, and the Z-axis positioning device section 31 supports one example of the migration positioning means of this invention.
[0016] The Z-axis positioning device section 31 is connected with the Z-axis servo motor 18 fixed to the column which is not illustrated, and the supporting structure 12 and the main shaft motor 13, and has the Z-axis slider 16 with which the screw section screwed in ball screw shaft 18a connected to the Z-axis servo motor 18 was formed, and the guide rail 17 installed in the column which holds the Z-axis slider 16 free [migration to Z shaft orientations], and which is not

illustrated.
[0017] From the Z-axis driver 52 connected to the Z-axis servo motor 18, a drive current is supplied and the rotation drive of the Z-axis servo motor 18 is carried out. Ball screw shaft 18a is prepared along the direction of Z shaft orientations, an end is connected to the Z-axis servo motor 18, and the other end is held free [rotation] by the attachment component prepared in the column which the above does not illustrate. Thereby, the Z-axis positioning device section 31 carries out migration positioning of the abrasive tools 3 held at the abrasive-tools attaching part 11 by the drive of the Z-axis servo motor 18 in the location of the arbitration of Z shaft orientations. Positioning accuracy of the Z-axis positioning device section 31 is made into the resolution of about 0.1 micrometers.
[0018] The wafer table 42 on which the X-axis migration device 41 acts as the tea king of the wafer W, The supporting structure 45 held for the wafer table 42, enabling free rotation, and the drive motor 44 which supplies the driving force which rotates the wafer table 42, The belt 46 which connects a drive motor 44 and the revolving shaft of the supporting structure 45, The processing pan 47 prepared in the supporting structure 45, and the X-axis slider 48 with which a drive motor 44 and the supporting structure 45 were installed, It has the X-axis servo motor 49 by which the pedestal was carried out to the stand which is not illustrated, ball screw shaft 49a connected to the X-axis servo motor 49, and moving-part material 49b in which the screw section which connects with the X-axis slider 48 and is screwed in ball screw shaft 49a was formed.
[0019] The wafer table 42 adsorbs Wafer W for example, with a vacuum adsorption means. The processing pan 47 is formed in order to collect the used electrolytic solution and liquids, such as a slurry. A drive motor 44 can be driven by supplying a drive current from the table driver 53, and the wafer table 42 can be rotated at a predetermined rotational frequency by controlling this drive current. According to the drive current supplied from the X-axis driver 54 connected to the X-axis servo motor 49, the X-axis servo motor 49 carries out a rotation drive, and the X-axis slider 48 drives it to X shaft orientations through ball screw shaft 49a and moving-part material 49b. At this time, speed control of X shaft orientations of the wafer table 42 is attained by controlling the drive current supplied to the X-axis servo motor 49.
[0020] Drawing 2 is drawing showing an example of the internal structure of the abrasive-tools attaching part 11. The abrasive-tools attaching part 11 is equipped with abrasive tools 3, the flange material 4 holding abrasive tools 3, the supporting structure 12 held for the flange material 4, enabling free rotation, the main shaft motor 13 which is connected with main shaft 12a held at the supporting structure 12, and is made to rotate the main shaft 12a concerned, and the cylinder equipment 14 formed on the main shaft motor 13.
[0021] The main shaft motor 13 consists of a direct drive motor, and Rota which this direct drive motor does not illustrate is connected with main shaft 12a held at the supporting structure 12. Moreover, the main shaft motor 13 has the through tube by which piston rod 14b of cylinder equipment 14 is inserted in a core. The main shaft motor 13 is driven according to the drive current supplied from the main shaft driver 51.
[0022] The supporting structure 12 is equipped for example, with air bearing, and holds main shaft 12a free [rotation] at this air bearing. Main shaft 12a of the supporting structure 12 also has the through tube by which piston rod 14b of cylinder equipment 14 is inserted in a core.
[0023] The flange material 4 is formed from the metallic material, it connected with main shaft 12a of the supporting structure 12, the pars basilaris ossis occipitalis was equipped with opening 4a, and abrasive tools 3 have fixed to lower limit side 4b. The upper limit side 4c side of the flange material 4 is connected with main shaft 12a held at the supporting structure 12, and also rotates the flange material 4 by rotation of main shaft 12a. Upper limit side 4c of the flange material 4 touches the energization brush 27 fixed to the conductive energization member 28 prepared in the side face of the main shaft motor 13 and the supporting structure 12, and the energization brush 27 and the flange material 4 are connected electrically.
[0024] It is fixed on the case of the main shaft motor 13, cylinder equipment 14 contains piston 14a, and piston 14a drives it with the pneumatic pressure supplied for example, in cylinder equipment 14 to one sense of the arrow heads A1 and A2. Piston rod 14b is connected with this piston 14a, and piston rod 14b passed along the core of the main shaft motor 13 and the supporting structure 12, and has projected from opening 4a of the flange material 4. The press member 21 is connected at the tip of piston rod 14b, and this press member 21 is connected with it in the predetermined range to piston rod 14b by the linkage in which posture modification is possible. The contact of the press member 21 is attained at the periphery section of opening 22a of the electric insulating plate 22 arranged in the location which counters, and it presses an electric insulating plate 22 by the drive to the arrow-head A 2-way of piston rod 14b.
[0025] The through tube is formed in the core of piston rod 14b of cylinder equipment 14, the energization shaft 20 is inserted into a through tube, and it is fixed to piston rod 14b. It is formed from the conductive ingredient and the upper limit side is extended to the rotary joint 15 which penetrated piston 14a of cylinder equipment 14, and was prepared on cylinder equipment 14, piston rod 14b and the press member 21 were penetrated, even the electrode plate 23 is extended, and the energization shaft 20 is connected to the electrode plate 23 by the lower limit side.
[0026] The through tube is formed in the core and the energization shaft 20 serves as a supply nozzle with which this

through tube supplies a chemical-polishing agent (slurry) and the electrolytic solution on Wafer W. Moreover, the energization shaft 20 has played the role which connects a rotary joint 15 and the electrode plate 23 electrically.

[0027] The rotary joint 15 connected to the upper limit section of the energization shaft 20 is electrically connected with the plus pole of the electrolysis electrode 61, and this rotary joint 15 maintains the energization to the energization shaft 20, even if the energization shaft 20 rotates. That is, even if the energization shaft 20 rotates, the potential of plus is impressed from the electrolysis electrode 61 by the rotary joint 15.

[0028] the metal membrane which the electrode plate 23 connected to the lower limit section of the energization shaft 20 consists of a metallic material, and is especially formed in Wafer W -- ** -- it is formed with the metal. The top-face side is held at the electric insulating plate 22, the periphery section of the electrode plate 23 has fitted into an electric insulating plate 22, and, as for the electrode plate 23, the scrub member 24 is stuck on the inferior-surface-of-tongue side.

[0029] Here, drawing 3 (a) is the bottom view showing an example of the structure of the electrode plate 23, and drawing 3 (b) is the sectional view showing the physical relationship of the electrode plate 23, and the energization shaft 20, the scrub member 24 and an insulating member 4. As shown in drawing 3 (a), circular opening 23a is prepared in the center section of the electrode plate 23, and two or more slot 23b extended to radial [of the electrode plate 23] focusing on this opening 23a at a radial is formed. Moreover, as shown in drawing 3 (b), fitting fixing of the lower limit section of the energization shaft 20 is carried out at opening 23a of the electrode plate 23. It is spread all over the scrub member 24 through slurry and electrolytic-solution fang furrow section 23b supplied by considering as such a configuration through supply nozzle 20a formed in the core of the energization shaft 20. That is, if a slurry and the electrolytic solution are supplied to the top side of the scrub member 24 through supply nozzle 20a formed in the core of the energization shaft 20 while the electrode plate 23, the energization shaft 20 and the scrub member 24, and an insulating member 4 rotate, a slurry and the electrolytic solution will spread in the whole top side of the scrub member 24. In addition, supply nozzle 20a of the scrub member 24 and the energization shaft 20 supports one example of the abrasive material supply means of this invention, and an electrolytic-solution supply means. Moreover, the electrode plate 23, the energization shaft 20, and the rotary joint 15 support one example of the energization means of this invention.

[0030] The scrub member 24 stuck on the inferior surface of tongue of the electrode plate 23 absorbs the electrolytic solution and a slurry, and is formed from the ingredient which can make a bottom side pass these from a top side. Moreover, this scrub member 24 is formed from the ingredient of the shape of a soft brush, a sponge-like ingredient, a porous ingredient, etc. so that the field which counters Wafer W may be the field which contacts Wafer W and carries out the scrub of the wafer W and a wafer W front face may not be made to generate a scratch etc. For example, the porous body which consists of resin, such as urethane resin, melamine resin, an epoxy resin, and a polyvinyl acetal (PVA), is mentioned.

[0031] The electric insulating plate 22 is formed from insulating materials, such as ceramics, and this electric insulating plate 22 is connected with main shaft 12a of the supporting structure 12 by the connection member 26 of the shape of two or more rod. The connection member 26 is arranged at equal intervals from the medial axis of an electric insulating plate 22 in the predetermined radius location, and is held free [migration] to main shaft 12a of the supporting structure 12. For this reason, the electric insulating plate 22 is movable to the shaft orientations of main shaft 12a. Moreover, between an electric insulating plate 22 and main shaft 12a, it connects by the elastic member 25 which consists of a coil spring corresponding to each connection member 26.

[0032] If high-pressure air is supplied to cylinder equipment 14 and piston rod 14b is dropped to the sense of an arrow head A2 by enabling migration of an electric insulating plate 22 to main shaft 12a of the supporting structure 12, and considering as the configuration which connects an electric insulating plate 22 and main shaft 12a by the elastic member 25, the press member 21 will depress an electric insulating plate 22 caudad against the stability of an elastic member 25, and the scrub member 24 will also descend with this. If supply of the high-pressure air from this condition to cylinder equipment 14 is suspended, according to the stability of an elastic member 25, an electric insulating plate 22 will go up and the scrub member 24 will also go up with this.

[0033] Abrasive tools 3 have fixed to annular lower limit side 4b of the flange material 4. These abrasive tools 3 are formed in the shape of a wheel, and equip the lower limit side with annular polished surface 3a. Abrasive tools 3 have conductivity and form it with the ingredient of elasticity nature comparatively preferably. for example, the carbon in which the binder matrix (binder) itself has conductivity -- or it can form from the porous body which consists of resin, such as urethane resin containing conductive ingredients, such as sintered copper and a metal compound, melamine resin, an epoxy resin, and a polyvinyl acetal (PVA). Direct continuation of the abrasive tools 3 is carried out to the flange material 4 which has conductivity, and they are energized from the energization brush 27 in contact with the flange material 4. That is, the conductive energization member 28 prepared in the side face of the main shaft motor 13 and the supporting structure 12 is electrically connected with the minus pole of the electrolysis power source 61, the

energization brush 27 formed in the energization member 28 touches upper limit side 4c of the flange material 4, and, thereby, abrasive tools 3 are electrically connected through the electrolysis power source 61, the energization member 28, the energization brush 27, and the flange material 4.
[0034] As abrasive tools 3 are shown in drawing 4 , polished surface 3a inclines at the minute include angle to a medial axis. Moreover, main shaft 12a of an attachment component 12 as well as the inclination of polished surface 3a inclines to the principal plane of Wafer W. For example, the minute inclination of main shaft 12a can be made by adjusting the installation posture to the Z-axis slider 16 of an attachment component 12. Thus, when the medial axis of abrasive tools 3 inclines at the minute include angle to the principal plane of Wafer W and polished surface 3a of abrasive tools 3 is forced on Wafer W by the predetermined processing pressure force F, the effectual operation field S to the wafer W of polished surface 3a turns into a field of the shape of a straight line extended to radial [of abrasive tools 3], as shown in drawing 4 . For this reason, in case Wafer W is moved to X shaft orientations to abrasive tools 3 and polish descent is performed, while moving to drawing 5 (b) from the condition of drawing 5 (a), the area of the effectual operation field S serves as abbreviation regularity. With the polish equipment 1 concerning this operation gestalt, make a part of polished surface 3a of abrasive tools 3 act on the front face of Wafer W partially, the front face of Wafer W is made to scan the effectual operation field S to homogeneity, and the whole surface of Wafer W is ground to homogeneity.
[0035] The electrolysis power source 61 is equipment which impresses a predetermined electrical potential difference between above-mentioned rotary joints 15 and energization brushes 12. By impressing an electrical potential difference between a rotary joint 15 and the energization brush 12, the potential difference occurs between abrasive tools 3 and the scrub member 24. Preferably, an electrical potential difference is outputted in the shape of a pulse a fixed period, for example, not the constant voltage power supply that always outputs a fixed electrical potential difference but the DC power supply which built in the switching regulator circuit are used for the electrolysis power source 61. A pulse-like electrical potential difference is outputted a fixed period, and, specifically, the power source which can be changed suitably is used for pulse width. As an example, output voltage used what DC150V and peak output current can change into either 2-3A, and whose pulse width are 1, 2, 5, 10, and 20 or 50 microseconds. It considers as the voltage output of the shape of a pulse with the above short width of face for making very small the electrolysis elution volume per one pulse. That is, the spark discharge by sudden change of the electric resistance started when discharge, air bubbles, particle, etc. by the sudden change of the distance between electrodes seen when it contacts, the irregularity of the metal membrane formed in the front face of Wafer W, intervene etc. is effective in order to make huge elution of the shape of a sudden crater of a metal membrane prevention or the continuation of a small thing controlled as much as possible. Moreover, as compared with the output current, since output voltage is comparatively high, a certain amount of margin can be set as a setup of the distance between electrodes. That is, even if the distance between electrodes changes somewhat, since output voltage is high, current value change is small.
[0036] The electrolysis power source 61 is equipped with the ammeter 62 as a current detection means of this invention, in order that this ammeter 62 may carry out the monitor of the electrolytic current which flows to the electrolysis power source 61, it is prepared, and 62s of current value signals which carried out the monitor is outputted to KONTORA 55. Moreover, it has the ohm-meter 63 as a resistance detection means of this invention, this ohm-meter 63 is established in order to carry out monitoring of the electric resistance between the abrasive tools 3 and the electrode plates 23 which went via the front face of Wafer W based on the current which flows to the electrolysis power source 61, and the electrolysis power source 61 outputs 63s of electric resistance value signals which carried out monitoring to KONTORA 55.
[0037] The slurry feeder 71 supplies a slurry to supply nozzle 20a of the above-mentioned energization shaft 20. The thing which made the water solution which has as a slurry the oxidizing power which used a hydrogen peroxide, iron nitrate, a potassium iodate, etc. as the base as an object for polish of a metal membrane contain an aluminum oxide (alumina), cerium oxide, a silica, a germanium dioxide, etc. as a polish abrasive grain is used. Moreover, a polish abrasive grain is just beforehand electrified, in order to improve dispersibility and to hold a colloidal state.
[0038] The electrolytic-solution feeder 81 supplies the electrolytic solution EL to the processing head section 11. The electrolytic solution EL is a solution which consists of a solvent and a solute separated in ion. As this electrolytic solution, the water solution which adjusted the reducing agent to the nitrate or the chloride system can be used.
[0039] A controller 55 has the function which controls the whole polish equipment 1. Specifically Output 51s of control signals to the main shaft driver 51, and the rotational frequency of abrasive tools 3 is controlled. Output 52s of control signals to the Z-axis driver 52, and point-to-point control of Z shaft orientations of abrasive tools 3 is performed. 53s of control signals is outputted to the table driver 53, the engine speed of Wafer W is controlled, 54s of control signals is outputted to the X-axis driver 54, and the speed is controlled in X shaft orientations of Wafer W. Moreover, a controller 55 controls actuation of the electrolytic-solution feeder 81 and the slurry feeder 71, and controls the electrolytic solution EL to the processing head section 2, and supply actuation of Slurry SL.
[0040] Moreover, a controller 55 is controllable in the output voltage of the electrolysis power source 61, the frequency

of an output pulse, the width of face of an output pulse, etc. Moreover, 62s of current value signals and 63s of electric resistance value signals from the ammeter 62 and ohm-meter 63 of the electrolysis power source 61 are inputted into a controller 55. A controller 55 is controllable in actuation of polish equipment 1 based on 62s of these current value signals, and 63s of electric resistance value signals. By making 62s of current value signals into a feedback signal, the Z-axis servo motor 18 controls, or actuation of polish equipment 1 is controlled based on the value of the current value specified by 62s of current value signals, and 63s of electric resistance value signals, and an electric resistance value to stop polish processing so that the electrolytic current acquired from 62s of current value signals specifically becomes fixed.

[0041] An operator inputs various kinds of data, or the control panel 56 connected to the controller 55 displays 62s of current value signals and 63s of electric resistance value signals which carried out monitoring.

[0042] Next, the case where the metal membrane formed in the wafer W front face in the polish actuation by the above-mentioned polish equipment 1 is ground is explained to an example. In addition, the case where the metal membrane which consists of copper is formed in the front face of Wafer W is explained. First, chucking of the wafer W is carried out to the wafer table 45, the wafer table 45 is driven, and Wafer W is rotated at a predetermined rotational frequency. Moreover, the wafer table 45 is moved to X shaft orientations, the abrasive tools 3 attached in the flange 4 are located in the upper predetermined location of Wafer W, and abrasive tools 3 are rotated at a predetermined rotational frequency. If abrasive tools 3 are rotated, the rotation drive also of the electric insulating plate 22 connected with the flange 4, the electrode plate 23, and the scrub member 24 will be carried out. Moreover, the press member 21 which is pressing the scrub member 24, piston rod 14b, piston 14a, and the energization shaft 20 also rotate to coincidence.

[0043] If Slurry SL and the electrolytic solution EL are supplied to supply nozzle 20a within the energization shaft 20, respectively from the slurry feeder 71 from this condition, and the electrolytic-solution feeder 81, Slurry SL and the electrolytic solution EL will be supplied from the whole surface of the scrub member 24. Abrasive tools 3 are dropped to Z shaft orientations, polished surface 3a of abrasive tools 3 is contacted on the front face of Wafer W, and it is made to press by the predetermined processing pressure force. Moreover, the electrolysis power source 61 is started, the potential of minus is impressed to abrasive tools 3 through the energization brush 27, and the potential of plus is impressed to the scrub member 24 through a rotary joint 15.

[0044] Furthermore, high-pressure air is supplied to cylinder equipment 14, piston rod 14b is dropped in the direction of the arrow head A2 of drawing 1 , and the inferior surface of tongue of the scrub member 24 is moved to Wafer W to the location contacted or approached. The wafer table 45 is moved to X shaft orientations by the predetermined rate pattern from this condition, and polish processing of the whole surface of Wafer W is carried out uniformly.

[0045] It is the schematic diagram showing the condition of drawing 6 having dropped abrasive tools 3 to Z shaft orientations in polish equipment 1, and having made the front face of Wafer W contacting here, drawing 7 is an enlarged drawing in the circle C of drawing 6 , and drawing 8 is an enlarged drawing in the circle D of drawing 7 . It energizes as cathode by contacting directly through the electrolytic solution EL supplied on Wafer W at the metal membrane MT which is energized as an anode plate by contacting directly through the electrolytic solution EL supplied on Wafer W at the metal membrane MT by which the scrub member 24 was formed in Wafer W as shown in drawing 7 , and by which abrasive tools 3 were also formed in Wafer W. In addition, as shown in drawing 7 , gap deltab exists between a metal membrane MT and the scrub member 24. Furthermore, as shown in drawing 8 , gap deltaw exists between a metal membrane MT and polished surface 3a of abrasive tools 3. It is the current i0 which is very large as for the resistance R0 of an electric insulating plate 4, therefore flows from the scrub member 24 to abrasive tools 3 through an electric insulating plate 4 although the electric insulating plate 4 intervenes between abrasive tools 3 and the scrub member 24 (electrode plate 23) as shown in drawing 7 . It is about 0 and a current does not flow from the scrub member 24 to abrasive tools 3 through an electric insulating plate 4.

[0046] For this reason, the current which flows from the scrub member 24 to abrasive tools 3 is the current i1 which flows to abrasive tools 3 via the resistance R1 in the direct electrolytic solution EL. It branches to current i2 which flows in the current which flows [be / it / under / electrolytic-solution EL / passing] to abrasive tools 3 again out of the electrolytic solution EL via the metal membrane MT which consists of copper formed in the front face of Wafer W. If current i2 flows on the front face of a metal membrane MT, the copper which constitutes a metal membrane MT will be ionized by the electrolytic action of the electrolytic solution EL, and will be eluted in the electrolytic solution EL.

[0047] Here, the resistance R1 in the electrolytic solution EL becomes extremely large in proportion to the distance d of the scrub member 24 as an anode plate, and the abrasive tools 3 as cathode. For this reason, current i1 which flows to abrasive tools 3 via the resistance R1 in the direct electrolytic solution EL by making the distance between electrodes d larger enough than gap deltab and gap deltaw It becomes very small, current i2 becomes large, and a metal membrane MT will carry out the surface course of most electrolytic current. For this reason, electrolysis elution of the copper which constitutes a metal membrane MT can be performed efficiently. Moreover, since the magnitude of current i2 changes

with the magnitude of gap deltab and gap deltaw, as mentioned above, it can make current i2 regularity by performing position control of Z shaft orientations of abrasive tools 3, and adjusting the magnitude of gap deltab and gap deltaw by the controller 55. Adjustment of the magnitude of gap deltaw is possible by controlling the Z-axis servo motor 18 by making 62s of current value signals into a feedback signal so that the electrolytic current acquired from 62s of current value signals, i.e., current i2, may become fixed. Moreover, the positioning accuracy of Z shaft orientations of polish equipment 1 is fully as high as the resolution of 0.1 micrometers, in addition since it is always maintained uniformly, whenever the activation-[making main shaft 12a incline at a minute include angle to the principal plane of Wafer W] touch area S controls the value of electrolytic current uniformly, it is made as current density is always fixed, and can also make the electrolysis elution volume of a metal membrane regularity.
[0048] as mentioned above, the electrolytic action according the metal which constitutes the metal membrane MT formed in the wafer W which mentioned above the polish equipment 1 of the above-mentioned configuration to the electrolytic solution EL -- it has the electrolytic-polishing function which carries out elution removal. Furthermore, in addition to this electrolytic-polishing function, the polish equipment 1 of the above-mentioned configuration is equipped also with the chemical machinery polish function of abrasive tools 3 and the usual CMP equipment by Slurry SL, and it can also perform grinding Wafer W according to these electrolytic-polishing function and a compound operation of chemical machinery polish (henceforth electrolysis compound polish). Moreover, the polish equipment 1 of the above-mentioned configuration can also perform polish processing according to a compound operation with mechanical polish and the electrolytic-polishing function of polished surface 3a of abrasive tools 3, without using Slurry SL. Since the polish equipment 1 of the above-mentioned configuration can grind a metal membrane according to a compound operation of electrolytic polishing and chemical machinery polish, it can remove a metal membrane in high efficiency far compared with the polish equipment only using chemical machinery polish or mechanical polishing. Since the high polish rate to a metal membrane is obtained, it becomes possible to suppress low the processing pressure force F over the wafer W of abrasive tools 3 compared with the polish equipment only using chemical machinery polish or mechanical polishing, and generating of dishing and erosion can be controlled.
[0049] The case where it applies to the wiring formation process by the dual DAMASHIN method of the semiconductor device of multilayer-interconnection structure hereafter about the polish approach using the electrolysis compound polish function of the polish equipment 1 concerning this operation gestalt is explained to an example.
[0050] < -- A HREF -- = -- " -- /-- Tokujitu/tjitemdrw . -- ipdl?N -- 0000 -- = -- 239 -- & -- N -- 0500 -- = -- one -- E_N -- /--; -- > -- < -- ? -- 88 -- > -- > -- eight -- /-- /-- /-- & -- N -- 0001 -- = -- 636 -- & -- N -- 0552 -- = -- nine -- & -- N -- 0553 -- = -- 000011 -- " -- TARGET -- = -- "tjitemdrw" -- > -- drawing 9 -- this invention -- a semiconductor device -- manufacture -- an approach -- one -- operation -- a gestalt -- starting -- manufacture -- a process -- be shown -- process drawing -- it is -- drawing 9 -- be shown -- process drawing -- be based -- a book -- operation -- a gestalt -- starting -- manufacture -- a process -- explaining . first, the interlayer insulation film 102 with which the impurity diffusion field which is not illustrated is suitably formed, for example, consists of silicon oxide (SiO_2) on the wafer W which consists of semi-conductors, such as silicon, as shown in drawing 10 -- as for example, the source of a reaction -- TEOS (tetraethylorthosilicate) using -- reduced pressure CVD (Chemical Vapour Deposition) -- it forms by law. Subsequently, as shown in drawing 11 , the slot 104 for wiring in which wiring of the predetermined pattern electrically connected with the impurity diffusion field of the contact hole 103 and Wafer W which lead to the impurity diffusion field of a wafer is formed is formed using a well-known photolithography technique and an etching technique, for example. In addition, the depth of the slot 104 for wiring is about 800nm.
[0051] Subsequently, as shown in drawing 12 , the barrier film 105 is formed in the front face of an interlayer insulation film 102 and a contact hole 103, and the slot 104 for wiring. This barrier film 305 is PVD (Physical Vapor Deposition) which used ingredients, such as Ta, Ti, TaN, and TiN, for the sputtering system, the vacuum evaporation system, etc. By law, it forms by about 15nm thickness. The barrier film 305 is formed in order that the ingredient which constitutes wiring may prevent being spread in an interlayer insulation film 102, and in order to raise adhesion with an interlayer insulation film 102. This is prevented, in order that especially copper may have a large diffusion coefficient to silicon oxide and a wiring material may tend to oxidize with copper, case [whose interlayer insulation film 102 is / like silicon oxide]. The process to the above is the process PR 1 shown in drawing 9 .
[0052] Subsequently, as shown in drawing 13 , the same ingredient 106 as a wiring formation ingredient, for example, the seed film which consists of copper, is formed by about 150nm thickness by the well-known spatter on the barrier film 105 (process PR 2). When copper is embedded in the slot for wiring, and a contact hole, the seed film 106 is formed in order to urge growth of a copper grain. Subsequently, as shown in drawing 14 , the metal membrane 107 which consists of copper is formed by about 2000nm thickness on the barrier film 105 so that a contact hole 103 and the slot 104 for wiring may be embedded. Preferably, although a metal membrane 107 is formed by electrolysis plating or the electroless deposition method, it may be formed by the CVD method, a spatter, etc. In addition, the seed film 106 is united with a metal membrane 107 (process PR 3).

[0053] Here, drawing 15 is the enlarged drawing of the cross section of the semiconductor device in the middle of the manufacture process in which the metal membrane 107 was formed on the barrier film 105. As shown in drawing 15 , in the front face of a metal membrane 107, irregularity with a height of about 600nm has occurred for the embedding to a contact hole 103 and the slot 104 for wiring. Although the above process is performed in the same process as usual, it performs removal of the excessive metal membrane 107 which exists on an interlayer insulation film 102, and the barrier film 105 by the polish approach of this invention not by chemical machinery polish but by electrolysis compound polish of above polish equipment 1. Moreover, by the polish approach of this invention, in advance of the process by the above-mentioned electrolysis compound polish, as shown in drawing 16 , the passive state film 108 is formed in the front face of a metal membrane 107 (process PR 4). This passive state film 108 is film which consists of an ingredient which demonstrates the operation which bars the electrolysis reaction of the metal (copper) which constitutes a metal membrane 107.
[0054] The formation approach of the passive state film 108 applies an oxidizer to the front face of a metal membrane 107, and forms an oxide film in it. When the metal which constitutes a metal membrane 107 is copper, copper oxide (CuO) serves as the passive state film 108. Moreover, it is also possible to form in the front face of a metal membrane 107 either for example, the **** water screen, an oil film, the antioxidizing film, the film that consists of a surfactant, the film which consists of a chelating agent and the film which consists of a silane coupling agent as other approaches, and to consider as the passive state film 108. Although especially the class of passive state film 108 is not limited, to a metal membrane 107, electric resistance is high and uses the thing of the property in which a mechanical strength is comparatively low and weak.
[0055] Next, by the polish approach of this invention, only the passive state film 108 formed in the heights of a metal membrane 107 is removed alternatively (process PR 5). Above polish equipment 1 performs alternative removal of the passive state film 108. In addition, a slurry with the high polish rate to copper is used for the slurry SL to be used. For example, what contains the polish abrasive grain of an alumina, a silica, and a manganese system in the water solution which used a hydrogen peroxide, iron nitrate, a potassium iodate, etc. as the base is used. First, carry out chucking of the wafer W to the wafer table 42 of polish equipment 1, and drop the abrasive tools 3 and the scrub member 24 which are rotated while supplying the electrolytic solution EL and Slurry SL on Wafer W to Z shaft orientations, Wafer W is made to contact or approach, Wafer W is moved to X shaft orientations by the predetermined rate pattern, and polish processing is performed. Moreover, a direct-current pulse voltage is impressed between abrasive tools 3 and the electrode plate 23 by making a minus pole and the electrode plate 23 into a plus pole at abrasive tools 3. In addition, Slurry SL may be supplied on Wafer W by giving the function of the electrolytic solution SL to the water solution used as the base of Slurry SL.
[0056] Here, drawing 17 is the conceptual diagram showing the polish process in the scrub member 24 neighborhood in the above-mentioned condition, and drawing 18 is the conceptual diagram showing the polish process in the abrasive-tools 3 neighborhood. As shown in drawing 17 , in the scrub member 24 neighborhood, Slurry SL and the electrolytic solution EL are supplied from slot 23b of the rotating electrode plate 23, and Slurry SL and the electrolytic solution EL pass the scrub member 24, and are supplied on Wafer W from the whole surface of the scrub member 24. The elution of the copper which constitutes the metal membrane 107 to the inside of the electrolytic solution EL has the passive state film 108 formed on the metal membrane 107 in the condition of having been controlled in order not to receive the electrolytic action by the electrolytic solution EL. For this reason, the current value in which a current hardly flowed to a metal membrane 107, but the above-mentioned ammeter 62 carried out the monitor has been stabilized low. Drawing 25 is a graph which shows an example of the current value which acted as the monitor with the ammeter 62 in the electrolysis compound polish process of this operation gestalt. Near the starting position of the current value shown in drawing 25 is in the above-mentioned condition.
[0057] According to rotation of the scrub member 24, it is contained in a mechanical removal operation or Slurry SL, for example, is mechanically removed from the passive state film 108 on the high part of the passive state film 108, i.e., the heights of a metal membrane 107, by the mechanical removal operation of the polish abrasive grain PT which consists of an aluminum oxide. On the other hand, as shown in drawing 18 , in the abrasive-tools 3 neighborhood, the passive state film 108 which exists in a metal membrane 108 according to a mechanical removal operation of abrasive tools 3 or a mechanical removal operation of the polish abrasive grain PT is removed from a high part.
[0058] Thus, if the passive state film 108 formed on the heights of a metal membrane 107 is alternatively removed for example, as shown in drawing 19 , a metal membrane 107 will be exposed to a front face from the part from which the passive state film 108 was removed alternatively.
[0059] If a metal membrane 107 is exposed to a front face, the exposed part of the metal membrane 107 which is heights will be eluted alternatively (process PR 5). As an operation of the electrolytic solution EL at this time is shown in drawing 18 , the copper with which the heights of the metal membrane 107 which is the part from which the passive state film 108 was removed constitute a metal membrane 107 is eluted in the electrolytic solution EL as copper ion Cu+

by the electrolytic action. By this, it is the minus electron e in a metal membrane 107. - It flows and is this minus electron e. - Current i2 which flowed and described above from the front face of a metal membrane 107 to the electrode plate 23 through the electrolytic solution EL as shown in drawing 17 It becomes.

[0060] As mentioned above, since electric resistance is low and current density of copper which constitutes a metal membrane 107 increases compared with the passive state film 108, an intensive electrolytic action is received, elution starts alternatively, and ingredient removal is accelerated. Moreover, in order to energize through the electrolytic solution EL, when the potential difference of the abrasive tools 3 as the metal membrane 107 and cathode as an anode plate is fixed, the current value to which the one where an electric resistance value is lower flows between poles becomes [the distance between electrodes] short greatly. For this reason, if there is a difference (the distance between electrodes is [the part high in the heights of a metal membrane 107] shorter, and electric resistance is low) of the inter-electrode distance by the irregularity of the metal membrane 107 as cathode to the abrasive tools 3 as cathode, efficient flattening to which a rate of dissolution becomes large at high order will advance from the difference in current density. At this time, in drawing 25 , as shown in P1, the current value in which the above-mentioned ammeter 62 carried out the monitor begins to rise. Compared with mechanical flattening, as for the heights of a metal membrane 107, flattening is far performed in high efficiency by such operation.

[0061] The front face of the metal membrane 107 which alternative electrolysis compound polish completed according to it until flattening of the heights of a metal membrane 107 was carried out nearly completely by the above-mentioned operation turns into a compound side of the new field of the copper from which the heights of the passive state film 108 which remains into the part which was the crevice of a metal membrane 107, and a metal membrane 107 were removed, as shown in drawing 20 .

[0062] Then, as shown in drawing 21 , the electrolysis compound polish which the electrolytic action by the mechanical removal and the electrolytic solution EL which are performed on the front face of this metal membrane 107 with the polish abrasive grain PT in abrasive tools 3 and Slurry SL compounded advances (process PR 7). As the mechanical strength of the passive state film 108 which remains at this time was mentioned above, since it is low compared with a copper new field, when electrolysis compound polish of the passive state film 108 is carried out, it is mainly removed by the mechanical work, and the copper front face in the bottom of it is exposed, and an electrolytic action increases in proportion to that area. When full removal of the passive state film 108 is carried out, the surface area of the copper which constitutes a metal membrane 107 serves as max. After rising with removal of the passive state film 108, the current value to which the current which could come, simultaneously acted as the monitor with the ammeter 62 went up from the location of P1 in drawing 25 turns into maximum, when P2 from which copper surface area serves as max shows. According to the process so far, flattening of the initial irregularity of the front face of a metal membrane 107 is completed.

[0063] Thus, since electrolysis compound polish of this operation gestalt is the polish electrochemically aided with the polish rate, it can be ground by the low processing pressure force compared with the usual chemical machinery polish. Even if it compares this as simple mechanical polish, it is very advantageous in respect of reduction of a scratch, the level difference relaxation engine performance, dishing, reduction of erosion, etc. Furthermore, since it can grind by the low processing pressure force, it is very advantageous when mechanical strength uses for the interlayer insulation film 102 the low dielectric constant film of an organic system and porosity low dielectric constant insulator layer which are easy to be destroyed in the low usual chemical machinery polish.

[0064] If electrolysis compound polish of the above-mentioned metal membrane 107 advances and the excessive metal membrane 107 is removed, as shown in drawing 22 , the barrier film 105 will be exposed (process P8). At this time, the current in which an ammeter 62 acts as a monitor takes maximum from the time of the passive state film 108 on the metal membrane 107 shown by P2 of drawing 25 being removed altogether, and it takes the value of abbreviation regularity until the barrier film 105 shown by P3 of drawing 25 is exposed. If the barrier film 105 is exposed, when ingredients, such as Ta, Ti, TaN, and TiN, are used, the current value which acted as the monitor with the ammeter 62 from the time of the electric resistance showing by P3 which exposure of the barrier film 105 of drawing 25 starts since it is large compared with copper will begin to fall, for example. In this condition, it is in the condition that the copper film for an ununiformity of a metal membrane 107 remains, and polish processing is suspended in this condition. As shown in P4 of drawing 25 , a controller 55 judges that the current value fell to the predetermined value, and a halt of this polish processing stops polish actuation of polish equipment 1.

[0065] Subsequently, the barrier film 105 is removed (process PR 9). In the process which removes this barrier film 105, to the barrier film 105 formed to the metal membrane 107 which consists of above-mentioned copper from ingredients, such as Ta, TaN, Ti, TiN, etc. instead of the slurry SL with a high polish rate, a polish rate is high and uses the slurry SL with a low polish rate to a metal membrane 107. That is, the selection ratio of the polish rate of the barrier film 105 and a metal membrane 107 uses the biggest possible slurry SL.

[0066] Furthermore, from a viewpoint which controls generating of dishing by the exaggerated polish, and erosion,

output voltage of the electrolysis power source 61 is made smaller than the above-mentioned process, and polish removal of the barrier film 105 is performed. Moreover, it is desirable to also make the processing pressure force of abrasive tools 3 smaller than the above-mentioned process. Moreover, since an interlayer insulation film 102 is exposed to a front face and the value of electrolytic current will become small if making small output voltage of the electrolysis power source 61 and the barrier film 105 are removed, it replaces with the monitor of the electrolytic current by the above-mentioned ammeter 62, and acts as the monitor of the electric resistance between the scrub member 24 and abrasive tools 3 with the above-mentioned ohm-meter 63.
[0067] Removal of the barrier film 105 exposes an interlayer insulation film 102 on a front face, as shown in drawing 23 (process P10). Since there are no metal membrane 107 and barrier film 105 for energizing on a front face as an anode plate in this exposed part as shown in drawing 23 when an interlayer insulation film 102 is exposed, energization by the scrub member 24 is intercepted and the electrolytic action in the exposed part of an interlayer insulation film 102 stops. At this time, the electric resistance value which acted as the monitor with the ohm-meter 63 begins to increase.
[0068] Here, like the case of the above-mentioned level difference relaxation of the heights of a metal membrane 107, instead of the passive state film 108, concentration of the current density to the residual part of a metal membrane 107 starts the barrier film 105 as a part with high electric resistance, and elution removal of the residual part of a metal membrane 107 is alternatively carried out between the parts and the exposed parts of the barrier film 105 into which a metal membrane 107 remains. Into the part which the electrolytic action stopped, only the mechanical ingredient removal operation by abrasive tools 3 and Slurry SL works actively.
[0069] By the way, in the usual chemical machinery polish, the polish rate selection ratio to the barrier film 105 and the interlayer insulation film 102 of a metal membrane 107 tends to be enlarged as much as possible, and it is going to secure the dimensional accuracy of the top face of an interlayer insulation film 102 by using the rate difference as a margin. For this reason, dishing of a metal membrane 107 has composition which is not avoided. Moreover, if a selection ratio is set up low, dishing can be lessened to some extent, but in order to be dependent on the homogeneity of the amount distribution of removal within a wafer side, dimensional accuracy is generated also when removal of the barrier film 105 and a metal membrane 107 is not enough. For this reason, in order for the barrier film 105 and a metal membrane 107 to prevent the undershirt polish which is in the condition which remained on the top face of an interlayer insulation film 102, the exaggerated polish for the ununiformity within a field of the amount of removal is needed, and aggravation of the erosion by this exaggerated polish is not avoided in essence. On the other hand, with this operation gestalt, if the homogeneity within a field of Wafer W is secured to some extent, high efficiency removal will be carried out because an electrolytic action works into the residual part of the barrier film 105 which remains on an interlayer insulation film 102, or a metal membrane 107, and elution will stop from the exposed part of an interlayer insulation film 102. For this reason, the dimensional accuracy of an interlayer insulation film 102 is secured automatically, and generating of dishing and erosion is controlled.
[0070] While the barrier film 105 formed from ingredients, such as Ta, TaN, Ti, and TiN, as mentioned above is completely removable, generating of dishing by the exaggerated polish and erosion can be controlled. Moreover, although a current value is low and a removal rate becomes slow by setting up mechanical load lightly absolutely in the removal process of the barrier film 105 mentioned above If there are few metal membranes 107 which the thickness which remains becomes from the copper film of residue of an uneven part Even if the amount of removal of the barrier film 105 of the barrier film 105 itself is small since it is thin compared with a metal membrane 107, and there are variation and an ununiformity in this process, the absolute value of dishing and erosion is made few to extent which can be disregarded, and can also shorten the processing time. Furthermore, since the polish approach concerning this operation gestalt is compound processing to which the electrochemical operation was added in addition to mechanical polish, also mechanically, as for the front face which carried out flattening, a damage can acquire a smooth field few.
[0071] Subsequently, when maximum, i.e., wiring formation, is completed by the electric resistance value based on the electric resistance value which acted as the monitor with the ohm-meter 63, the process which removes the barrier film 105 is ended (process PR 11). A controller 55 judges the value of an electric resistance value, and stops processing actuation of polish equipment 1. In addition, by not contacting abrasive tools 3 on the front face of Wafer W, for example, passing about 100 micrometers of tops in the condition [having added the electrolytic action], before ending polish processing, mechanical polish cannot be performed but the front face of the damage free-lancer only by the electrolytic action can be formed. Thereby, as shown in drawing 23 , finally into an interlayer insulation film 102, wiring 109 and contact 110 are formed.
[0072] Subsequently, Flushing is performed to the semiconductor device with which wiring 109 and contact 110 were formed (process PR 12). Supplying a washing drug solution and an antioxidant to the front face of Wafer W immediately, after wiring 109 and contact 110 are formed, as it does not energize to Wafer W but is shown in drawing 24 , this Flushing process impresses the pulse voltage of plus to abrasive tools 3, performs pure-water washing and drug solution washing, and removes Slurry SL and particle which exist in the front face of Wafer W. Since it is contained in

Slurry SL, for example, the polish abrasive grain PT which consists of an alumina is just electrified with this operation gestalt in order to improve dispersibility also before performing Flushing, Also when it remains without wearing out after colliding with metal membrane 107 front face which consists of copper mechanically and contributing to removal processing, as it is not buried in the front face of the copper which constitutes the metal membrane 107 as an anode plate and was shown in drawing 23 , the reattachment is carried out to the front face of the abrasive tools 3 as cathode, and it contributes to the next processing. Furthermore, since the just charged particle can also be drawn near to the front face of the abrasive tools 3 as cathode, it is not buried on the surface of copper. The particle which remained on the front face of Wafer W and has been charged in negative on the other hand is also removable from the front face of Wafer W with above-mentioned Flushing. Moreover, when the slurry SL to which the polish abrasive grain PT was charged in negative is used, it can remove similarly. Although it is necessary to remove a metal ion and PAIKURU, without being easy to oxidize and deteriorating a copper front face when a wiring formation ingredient is copper, with this operation gestalt, the polish abrasive grain PT is just electrified beforehand, and this problem is solved by Flushing. In addition, as a polish abrasive grain, although the aluminum oxide (alumina) was mentioned as an example, it is also the same as when cerium oxide, a silica, a germanium dioxide, etc. are used.
[0073] As mentioned above, according to the manufacture approach of the semiconductor device concerning this operation gestalt, the passive state film 108 is formed in the metal membrane 107 which embeds slot wiring for wiring and the contact hole which were formed in the insulator layer 102. The passive state film 108 formed in the heights of a metal membrane 107 is removed alternatively. Compared with the usual CMP, flattening of the initial irregularity can be far carried out to high efficiency by electrolytic polishing removing alternatively the metal membrane 107 exposed to the front face by using the remaining passive state film 108 as a mask, and removing intensively by concentration to current density. Moreover, since the metal membrane 107 to which flattening of the initial irregularity was carried out is removed by the electrolysis compound polish which electrolytic polishing and chemical machinery polish compounded, it can remove the excessive metal membrane 107 in high efficiency far compared with the usual CMP. For this reason, even if it sets up the processing pressure force of abrasive tools 3 low, while sufficient polish rate is obtained and being able to mitigate the damage to a metal membrane 107, generating of dishing or erosion can be controlled.
[0074] Moreover, when according to the manufacture approach of the semiconductor device concerning this operation gestalt the excessive metal membrane 107 is removed and the barrier film 105 is exposed In order to stop polish, to change Slurry SL into what has a high polish rate to the barrier film 105, to change polish conditions, such as output voltage of the electrolysis power source 61, and to remove the excessive barrier film 105, The excessive barrier film 105 is certainly removable, and also when an exaggerated polish is required, the yield of dishing or erosion can be stopped small.
[0075] Moreover, in order to grind a metal membrane in high efficiency by electrolysis compound polish according to the manufacture approach of the semiconductor device concerning this operation gestalt, Since the processing pressure force of abrasive tools 3 can be made into the low voltage force, for example In order to reduce a dielectric constant from viewpoints, such as low-power-izing and improvement in the speed, also when a mechanical strength uses the comparatively low organic system low dielectric constant film and a porosity low dielectric constant insulator layer as an interlayer insulation film 102, the damage to these insulator layers can be reduced.
[0076] The absolute value of the amount of polish processings of a metal membrane is controllable by the time amount which passes the amount of addition of electrolytic current, and the wafer W of abrasive tools 3 with the operation gestalt mentioned above. With the operation gestalt mentioned above, although the case of the wiring formation process by copper was explained, this invention can be applied to various metal wiring formation processes, such as a tungsten, aluminum, and silver, without being limited to this.
[0077] Moreover, although the operation gestalt mentioned above explained the case of the electrolysis compound polish which compounded the chemical machinery polish which used Slurry SL, and electrolytic polishing using the electrolytic solution EL, this invention is not limited to this. That is, this invention can also perform electrolysis compound polish by electrolytic polishing of the electrolytic solution EL, and mechanical polishing by polished surface 3a of abrasive tools 3, without using Slurry SL.
[0078] Moreover, although the polish process until it acts as the monitor of the current value which flows between abrasive tools 3 and the electrode plates 23 and the barrier film 105 is exposed based on this value was managed with the operation gestalt mentioned above, it is also possible to manage all polish processes with the current value which acted as the monitor. Although similarly it acted as the monitor of the electric resistance value between abrasive tools 3 and the electrode plate 23 and being considered as the configuration which manages only the removal process of the barrier film 105 with the operation gestalt mentioned above based on this value, it is also possible to manage all polish processes with the electric resistance value which acted as the monitor.
[0079] Modification 1 drawing 26 is the schematic diagram showing the example of a complete-change form of the polish equipment concerning this invention. With the polish equipment 1 concerning the operation gestalt mentioned

above, conductive abrasive tools and the energization plate 23 equipped with the scrub member 24 performed energization to a wafer W front face. As shown in drawing 26 , the wheel-like abrasive tools 401 are good also as a configuration which also gives conductivity to the wafer table 402 which carries out chucking of the wafer W and is made to rotate it while they give conductivity as well as the case of polish equipment 1. Electric supply to abrasive tools 401 is performed with the same configuration as the operation gestalt mentioned above. In this case, the energization to the wafer table 402 can form a rotary joint 403 in the lower part of the wafer table 402, and electrolytic current can be supplied by considering energization to the wafer table 402 which rotates by the rotary joint 403 as the always maintained configuration.

[0080] Modification 2 drawing 27 is the schematic diagram showing other modifications of the polish equipment concerning this invention. Chucking of the wafer W is carried out and the wafer table 502 to rotate is held by the retainer ring 504 which formed Wafer W in the perimeter of Wafer W. While giving conductivity, conductivity is also given to a retainer ring 504 and electric power is supplied to abrasive tools 501 with the same configuration as the operation gestalt mentioned above at abrasive tools 501. Moreover, a retainer ring 504 is covered and energized to the part for the above-mentioned barrier layer formed in Wafer W. Furthermore, electric power is supplied to a retainer ring 504 through the rotary joint 503 prepared in the lower part of the wafer table 502. In addition, even if abrasive tools 501 contact Wafer W, interference with abrasive tools 501 and a retainer ring 504 can be prevented by enlarging the amount of inclinations of abrasive tools 3 so that the clearance more than the thickness of a retainer ring 504 can be maintained in the part of an edge.

[0081] Modification 3 drawing 28 is the outline block diagram showing other operation gestalten of the polish equipment concerning this invention. The polish equipment shown in drawing 28 is polish equipment which adds the electrolytic-polishing function of this invention to the CMP equipment of a conventional type, is contacted, rotating the whole surface of the wafer W in which chucking was carried out to the polished surface of abrasive tools where the scouring pad (abrasive cloth) 202 was stuck on the surface plate 201 by the wafer chuck 207, and carries out flattening of the front face of Wafer W. The anode plate electrode 204 and the cathode electrode 203 are arranged by turns at the radial at the scouring pad 202. Moreover, it insulates electrically with the insulator 206 and the anode plate electrode 204 and the cathode electrode 203 energize the anode plate electrode 204 and the cathode electrode 203 from a surface plate 201 side. The scouring pad 202 is constituted by these anode plate electrode 204, the cathode electrode 203, and the insulator 206. Moreover, the wafer chuck 207 is formed from the insulating material. Furthermore, the feed zone 208 which supplies the electrolytic solution EL and Slurry SL is formed in the front face of a scouring pad 202 at this polish equipment, and the electrolysis compound polish which compounded electrolytic polishing and chemical machinery polish is attained.

[0082] Here, drawing 29 is drawing for explaining the electrolysis compound polish actuation by the polish equipment of the above-mentioned configuration. In addition, the copper film 210 shall be formed in a wafer W front face. During electrolysis compound polish, as shown in drawing 29 , after the electrolytic solution EL and Slurry SL have intervened between the copper film 210 formed in the wafer W front face, and the polished surface of a scouring pad 202, direct current voltage is impressed between the anode plate electrode 204 and the cathode electrode 203, Current i is transmitted to the inside of a copper film 210 through the electrolytic solution EL from the anode plate electrode 204, and it flows to the cathode electrode 203 through the electrolytic solution EL again. Near [in the circle G shown in drawing 29 at this time], while a copper film 210 is eluted by the electrolytic action, a copper film 210 is further removed by the mechanical removal operation by the scouring pad 202 and Slurry SL.

[0083] By considering as such a configuration, the same effectiveness as the polish equipment 1 concerning the operation gestalt mentioned above is done so. In addition, arrangement of the anode plate electrode prepared in a scouring pad and a cathode electrode is good also as a scouring pad 221 with which two or more linear anode plate electrodes 222 were arranged at equal intervals in all directions, the cathode electrode 223 has been arranged to each rectangle field surrounded with the anode plate electrode 222, and the anode plate electrode 222 and the cathode electrode 223 were electrically insulated with the insulator 224, as it is not necessarily limited to the configuration of drawing 28 , for example, is shown in drawing 30 . Furthermore, it is good also as a scouring pad 241 with which the annular anode plate electrode 242 with which radii differ, respectively has been arranged on this alignment, the cathode electrode 243 has been arranged to the ring domain formed between each anode plate electrode 242, respectively, and the anode plate electrode 242 and the cathode electrode 243 were electrically insulated with the insulator 244, for example as shown in drawing 31 .

[0084]

[Effect of the Invention] According to this invention, since a metal membrane is ground according to a compound operation with mechanical polishing and electrolytic polishing, compared with the case of flattening of the metal membrane by mechanical polishing, alternative removal and flattening of the heights of a metal membrane become possible very much at high efficiency. Moreover, according to this invention, since abrasive tools are energized as

cathode, the polish abrasive grain in the particle just charged beforehand or an abrasive material can draw near to abrasive tools, and can prevent remaining to a wafer front face, and improvement in the yield can be aimed at. Moreover, according to this invention, since it becomes high efficiency removable [a metal membrane], it can control that polish rate sufficient also by the comparatively low polishing pressure force is obtained, and a scratch, dishing, erosion, etc. occur in the ground metal membrane. Furthermore, in order to obtain sufficient polish rate, to accumulate also by the comparatively low polishing pressure force and to reduce a dielectric constant from viewpoints, such as low-power-izing of a semiconductor device, and improvement in the speed, also when a mechanical strength uses the comparatively low organic system low dielectric constant film and a porosity low dielectric constant insulator layer as an interlayer insulation film according to this invention, it can apply easily. Moreover, according to this invention, since it is efficiently removed because an electrolytic action works, and elution stops from the exposed part of an insulator layer, the part of the barrier film which remains on an interlayer insulation film, or a metal can secure the stopping accuracy of polish automatically, and can control dishing and erosion. Moreover, according to this invention, a polish process can be managed by carrying out monitoring of the electrolytic current, and it becomes possible to grasp the advance condition of a polish process correctly. Moreover, according to this invention, by carrying out monitoring of the electric resistance value between abrasive tools and an electrode member, a current cannot flow easily, or even when grinding to coincidence the film and metal membrane to which a current does not flow, a polish process can be managed correctly.

[Translation done.]

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CLAIMS

[Claim(s)]
[Claim 1] So that the process which forms the slot for wiring for forming wiring in the insulator layer formed on the substrate, and said slot for wiring may be embedded The process which forms the passive state film which demonstrates the operation which bars the electrolysis reaction of the metal membrane concerned in the front face of the process which makes a metal membrane deposit on said insulator layer, and the metal membrane deposited on said insulator layer, The process which mechanical polishing removes [process] alternatively the immobilization film on the heights which exist in the front face of said metal membrane produced by the embedding of said slot for wiring among the passive state film formed in said metal membrane, and exposes the heights of the metal concerned on a front face, The manufacture approach of a semiconductor device of having the process which carries out flattening of the irregularity of the front face of said metal membrane which removed the heights of said exposed metal membrane by electrolytic polishing, and was produced by the embedding of said slot for wiring.
[Claim 2] the electrolysis compound polish which compounded electrolytic polishing and mechanical polishing for the excessive metal membrane to which said front face exists on said insulator layer of the metal membrane by which flattening was carried out -- the manufacture approach of a semiconductor device according to claim 1 of having further the process which removes and forms said wiring.
[Claim 3] Said electrolysis compound polish is the manufacture approach of a semiconductor device according to claim 2 of compounding electrolytic polishing and chemical machinery polish.
[Claim 4] The barrier film which consists of a conductive ingredient for preventing the diffusion to said insulator layer of said metal membrane so that said insulator layer top and said Mizouchi may be covered after forming said slot for wiring is formed. The process removed until said barrier film exposes to a front face the excessive metal membrane which exists on said insulator layer by said electrolysis compound polish, after carrying out flattening of the heights of said exposed metal membrane, The manufacture approach of a semiconductor device according to claim 2 of having the process removed by said electrolysis compound polish until said insulator layer exposes to a front face the excessive barrier film which exists on said insulator layer.
[Claim 5] Make the electrolytic solution intervene between the polished surface of the abrasive tools which have conductivity, and said passive state film, make said metal membrane and the barrier film into an anode plate, and said abrasive tools are used as cathode. Impress an electrical potential difference between said metal membrane and the barrier film, and said abrasive tools, and said abrasive tools are moved to it relatively [front face / of said passive state film]. The manufacture approach of the semiconductor device according to claim 4 to which elution of the heights of said metal membrane which removed alternatively the passive state film formed in the heights of said metal membrane, and was exposed from said passive state film removed alternatively is carried out by the electrolytic action of said electrolytic solution.
[Claim 6] The manufacture approach of a semiconductor device according to claim 5 of making the electrode member to which the electrical potential difference was impressed between said abrasive tools contacting or approaching said metal membrane and the barrier film, energizing on said metal membrane and said barrier film, carrying out monitoring of the current which flows from said electrode member to said abrasive tools via said said metal membrane and said barrier film, and managing advance of polish of said metal membrane and the barrier film based on the magnitude of the current value concerned.
[Claim 7] The manufacture approach of a semiconductor device according to claim 5 of making the electrode member to which the electrical potential difference was impressed between said abrasive tools contacting or approaching said metal membrane and the barrier film, energizing on said metal membrane and said barrier film, carrying out monitoring of the magnitude of the electric resistance generated between said electrode members and said abrasive tools, and managing advance of polish of said metal membrane and the barrier film based on the electric resistance value concerned.
[Claim 8] The manufacture approach of a semiconductor device according to claim 5 of making the chemical-polishing

agent containing a polish abrasive grain intervening between the polished surface of said abrasive tools, and said passive state film, and removing said passive state film alternatively.
[Claim 9] The manufacture approach of a semiconductor device according to claim 5 of removing said excessive metal membrane and barrier film using a different chemical-polishing agent with a respectively high polish rate to each ingredient which constitutes said metal membrane and said barrier film, respectively.
[Claim 10] The manufacture approach of the semiconductor device according to claim 5 made lower than the electrical potential difference which impresses the electrical potential difference impressed between said barrier film and said abrasive tools at the process which removes said excessive barrier film between said metal membranes and said abrasive tools in the process which removes said excessive metal membrane.
[Claim 11] The process which the process which forms said slot for wiring has the process which forms the contact hole for connecting the impurity diffused layer or wiring formed in the lower layer of said insulator layer, and wiring formed on the insulator layer concerned with formation of said slot for wiring, and embeds a metal in said slot for wiring is the manufacture approach of the semiconductor device according to claim 2 which embeds a metal with said slot for wiring in said contact hole.
[Claim 12] The manufacture approach of the semiconductor device according to claim 11 which uses copper for the formation ingredient of said wiring, and embeds copper in said slot for wiring and contact hole using an electroplating method.
[Claim 13] The manufacture approach of a semiconductor device according to claim 4 of using either Ta, Ti, TaN and TiN for the formation ingredient of said barrier film.
[Claim 14] Said passive state film is the manufacture approach of the semiconductor device according to claim 1 which consists of an oxide film which oxidized the front face of said metal membrane.
[Claim 15] The manufacture approach of the semiconductor device according to claim 14 which supplies an oxidizer to the front face of said metal membrane, and forms said oxide film.
[Claim 16] Said passive state film is the manufacture approach of the semiconductor device according to claim 1 which forms the film which consists of an ingredient which demonstrates the operation which bars the electrolysis reaction of the metal which constitutes said metal membrane on the front face of said metal membrane.
[Claim 17] Said passive state film is the manufacture approach of the semiconductor device according to claim 16 which forms in the front face of said metal membrane either the **** water screen, an oil film, the antioxidizing film, the film that consists of a surfactant, the film which consists of a chelating agent and the film which consists of a silane coupling agent.
[Claim 18] Said passive state film is the manufacture approach of a semiconductor device according to claim 1 with high and electric resistance and a mechanical strength lower than said metal membrane.
[Claim 19] The abrasive tools which have a polished surface and have conductivity, and an abrasive-tools rotation maintenance means to rotate and hold said abrasive tools centering on a predetermined revolving shaft, The rotation maintenance means which holds a ground object and is rotated centering on a predetermined revolving shaft, The migration positioning means which carries out migration positioning of said abrasive tools in the target position of the direction which counters said ground object, A relative-displacement means to make the polished surface-ed of said ground object, and the polished surface of said abrasive tools displaced relatively along a predetermined flat surface, Polish equipment which has an electrolytic-solution supply means to supply the electrolytic solution on the polished surface-ed of said ground object, and an electrolytic current supply means to supply the electrolytic current which makes an anode plate the polished surface-ed of said ground object, and flows from said polished surface-ed to said abrasive tools through said electrolytic solution by using said abrasive tools as cathode.
[Claim 20] Polish equipment according to claim 19 which has further an abrasive material supply means to supply the chemical-polishing agent containing a polish abrasive grain to the polished surface-ed of said ground object.
[Claim 21] Said electrolytic current supply means is polish equipment [equipped with the DC power supply which impress predetermined potential between an energization means for it to be arranged possible / contact to the polished surface-ed of said ground object /, or possible / approach /, and to energize to the polished surface-ed concerned by making the polished surface-ed of said ground object into an anode plate, and said energization means and said abrasive tools] according to claim 1.
[Claim 22] Said DC power supply are polish equipment according to claim 21 which outputs the electrical potential difference of the shape of a pulse of a predetermined period.
[Claim 23] It is polish equipment [equipped with the conductive electrode plate which said abrasive tools consist of a conductive wheel-like member, and the annular end side of the member concerned constitutes the polished surface, and said energization means is isolated with the abrasive tools concerned inside said abrasive tools, is formed in it, is held by said rotation maintenance means, and rotates with said abrasive tools] according to claim 21.
[Claim 24] Said electrode plate is polish equipment [equipped with the scrub member which has the field which carries

out the scrub of the polished surface-ed concerned to the side which counters the polished surface-ed of said ground object] according to claim 23.
[Claim 25] Said scrub member is polish equipment according to claim 24 which supplies the electrolytic solution and/or the chemical-polishing agent which are formed from the ingredient which can absorb the chemical-polishing agent containing said electrolytic solution and a polish abrasive grain, and can be passed, and are supplied from said electrode plate side to the polished surface-ed of a ground object.
[Claim 26] Said abrasive tools are polish equipment according to claim 21 energized through the energization brush which is held by the conductive member connected with said rotation maintenance means, and contacts said conductive member to rotate.
[Claim 27] the electrolyzed metal with which said electrode member was formed in the polished surface-ed of said ground object -- receiving -- ** -- the polish equipment according to claim 23 which consists of a metal.
[Claim 28] Polish equipment according to claim 19 further equipped with a current detection means to detect the value of the electrolytic current which flows from the polished surface-ed of said ground object to said abrasive tools.
[Claim 29] Polish equipment [equipped with a resistance detection means to detect the electric resistance between said electrode member in which it went via the polished surface-ed of said ground object, and said abrasive tools] according to claim 23.
[Claim 30] Polish equipment according to claim 29 which has further the control means which controls the location of the opposite direction of said abrasive tools and said ground object based on the detecting signal of said current detection means so that the value of said electrolytic current becomes fixed.
[Claim 31] It has the abrasive tools which have the polished surface which contacts while rotating all over the polished surface-ed of a ground object. It is polish equipment which is contacted making said polished surface rotate said ground object, and carries out flattening polish. Have an electrolytic-solution supply means to supply the electrolytic solution on said polished surface, and said polished surface is equipped with the anode plate electrode and cathode electrode of said ground object which can be energized to a polished surface-ed. Polish equipment which carries out flattening polish of the polished surface-ed of said ground object by electrolysis compound polish which compounded electrolytic polishing by said electrolytic solution, and mechanical polishing by said polished surface.
[Claim 32] Polish equipment according to claim 31 which carries out flattening polish of the polished surface-ed of said ground object by electrolysis compound polish which has further an abrasive material supply means to supply the chemical-polishing agent containing a polish abrasive grain to said polished surface, and compounded the chemical machinery polish by electrolytic polishing by said electrolytic solution, said polished surface, and said abrasive material.
[Claim 33] Make the electrolytic solution intervene, force the polished surface of conductive abrasive tools, and the front face of the ground object with which the metal membrane was formed in the front face or the inner layer at least, use said abrasive tools as cathode, and the front face of said ground object is made into an anode plate. The electrolytic current which flows from the front face of said ground object through said electrolytic solution to said abrasive tools is supplied. The polish approach which carries out flattening of the metal membrane formed in said ground object of the electrolysis compound polish which was made displaced relatively along a predetermined flat surface, rotating both said abrasive tools and said ground object, and compounded said electrolytic-solution **** electrolytic polishing and mechanical polishing by said polished surface.
[Claim 34] The polish approach according to claim 33 which carries out flattening of the metal membrane formed in said ground object of the electrolysis compound polish which the chemical-polishing agent which contains a polish abrasive grain with said electrolytic solution was made to intervene between said polished surface and the front face of said ground object, and compounded the chemical machinery polish by electrolytic polishing by said electrolytic solution, said polished surface, and said abrasive material.
[Claim 35] The polish approach according to claim 33 of the laminating of two or more film which becomes said ground object from a different ingredient being carried out, carrying out monitoring of the electrolytic current which flows from the front face of said ground object to said abrasive tools through said electrolytic solution which changes with the differences in the electrical characteristics of the ingredient of each of said film, and managing advance of polish based on the magnitude of the electrolytic current concerned.
[Claim 36] The polish approach according to claim 33 which impresses the electrical potential difference of the shape of a pulse of a predetermined period between said abrasive tools and the front face of said ground object, and supplies said electrolytic current to it.
[Claim 37] The polish approach according to claim 33 which is made to approach or contact the front face of said ground object with which the electrode member was supplied to said electrolytic solution, and is energized to the front face of said ground object.
[Claim 38] The polish approach according to claim 37 energized to the metal membrane formed in said ground object while rotating said electrode member with said abrasive tools and you made it displaced relatively to said ground object.

[Claim 39] The polish approach according to claim 37 of managing advance of polish of said ground object based on the magnitude of the electric resistance between said electrode member in which it went via the front face of said ground object, and said abrasive tools.
[Claim 40] The polish approach according to claim 34 of just electrifying the polish abrasive grain contained in said abrasive material.
[Claim 41] The process which forms the passive state film which demonstrates the operation which bars the electrolysis reaction of the metal membrane concerned in the front face of the metal membrane formed in the ground object, The process which the electrolytic solution is made to intervene between the polished surface of conductive abrasive tools, and said metal membrane, and forces a polished surface and a metal membrane concerned, and impresses a predetermined electrical potential difference in between with said abrasive tools and said metal membrane, The polished surface of said abrasive tools and the metal membrane of said ground object are made displaced relatively along a predetermined flat surface. The process which removes alternatively the passive state film on the heights projected to the polished surface of said abrasive tools among said metal membranes by mechanical polishing of said abrasive tools, The polish approach of having the process which removes the heights of the metal membrane which said passive state film was removed and was exposed to the front face according to the electrolytic-polishing operation by said electrolytic solution, and carries out flattening of said metal membrane.
[Claim 42] The polish approach according to claim 41 that make the chemical-polishing agent which contains a polish abrasive grain with said electrolytic solution intervene between said polished surfaces and said metal membranes, and the chemical machinery polish by said polished surface and said polish abrasive grain removes said passive state film alternatively.
[Claim 43] Said passive state film is the polish approach according to claim 41 which consists of an oxide film which oxidized the front face of said metal membrane.
[Claim 44] Said passive state film is the polish approach according to claim 41 which forms the film which consists of an ingredient which demonstrates the operation which bars the electrolysis reaction of the metal which constitutes said metal membrane on the front face of said metal membrane.
[Claim 45] Said passive state film is the polish approach according to claim 41 that electric resistance is high and a mechanical strength is lower than said metal membrane.
[Claim 46] The polish approach according to claim 41 which an electrode member is made to approach or contact the front face of said metal membrane, and is energized to said metal membrane.
[Claim 47] The polish approach according to claim 46 of managing advance of polish based on the magnitude of the electric resistance between said electrode members and said abrasive tools.
[Claim 48] The polish approach according to claim 42 of just electrifying the polish abrasive grain contained in said abrasive material.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is drawing showing the configuration of 1 operation gestalt of the polish equipment of this invention.
[Drawing 2] It is the enlarged drawing showing the detail of the head section of the polish equipment of drawing 1 .
[Drawing 3] (a) is the bottom view showing an example of the structure of the electrode plate 23, and (b) is the sectional view showing the physical relationship of the electrode plate 23, and the energization shaft 20, the scrub member 24 and an insulating member 4.
[Drawing 4] It is drawing showing the relation between abrasive tools and a wafer.
[Drawing 5] It is drawing showing signs that the wafer was moved to X shaft orientations to abrasive tools.
[Drawing 6] It is the schematic diagram showing the condition of carrying out polish processing of the wafer in the head processing section.
[Drawing 7] It is drawing showing the relation between abrasive tools and an electrode plate.
[Drawing 8] It is drawing for explaining the electrolytic-polishing function of the polish equipment of this invention.
[Drawing 9] It is process drawing showing the manufacture process concerning 1 operation gestalt of the manufacture approach of the semiconductor device of this invention.
[Drawing 10] It is the sectional view showing the manufacture process of the manufacture approach of the semiconductor device of this invention.
[Drawing 11] It is the sectional view showing the manufacture process following drawing 10 .
[Drawing 12] It is the sectional view showing the manufacture process following drawing 11 .
[Drawing 13] It is the sectional view showing the manufacture process following drawing 12 .
[Drawing 14] It is the sectional view showing the manufacture process following drawing 13 .
[Drawing 15] It is the enlarged drawing of the cross-section structure of the semiconductor device shown in drawing 14 .
[Drawing 16] It is the sectional view showing the manufacture process following drawing 14 .
[Drawing 17] It is the conceptual diagram showing the polish process in the scrub member 24 neighborhood.
[Drawing 18] It is the conceptual diagram showing the polish process in the abrasive-tools 3 neighborhood.
[Drawing 19] It is the sectional view showing the manufacture process following drawing 16 .
[Drawing 20] It is the sectional view showing the condition that the heights of a metal membrane were removed alternatively and flattening was carried out.
[Drawing 21] It is the sectional view showing the manufacture process following drawing 19 .
[Drawing 22] It is the sectional view showing the manufacture process following drawing 21 .
[Drawing 23] It is the sectional view showing the manufacture process following drawing 22 .
[Drawing 24] It is the sectional view showing the condition of having carried out Flushing to the semiconductor device which polish processing ended.
[Drawing 25] It is the graph which shows an example of the current value which acted as the monitor in the electrolysis compound polish process.
[Drawing 26] It is drawing showing the modification of the polish equipment of this invention.
[Drawing 27] It is drawing showing the modification of further others of the polish equipment of this invention.
[Drawing 28] It is the outline block diagram showing other operation gestalten of the polish equipment concerning this invention.
[Drawing 29] It is drawing for explaining the electrolysis compound polish actuation by the polish equipment shown in drawing 28 .
[Drawing 30] It is drawing showing other examples of the electrode configuration of a scouring pad.
[Drawing 31] It is drawing showing the example of further others of the electrode configuration of a scouring pad.
[Drawing 32] It is the sectional view showing the wiring formation process by the dual DAMASHIN method.

[Drawing 33] It is the sectional view showing the wiring formation process following drawing 32 .
[Drawing 34] It is the sectional view showing the wiring formation process following drawing 33 .
[Drawing 35] It is the sectional view showing the wiring formation process following drawing 34 .
[Drawing 36] It is the sectional view showing the wiring formation process following drawing 35 .
[Drawing 37] It is the sectional view showing the wiring formation process following drawing 36 .
[Drawing 38] It is a sectional view for explaining dishing generated in polish processing in the metal membrane by the CMP method.
[Drawing 39] It is a sectional view for explaining the erosion generated in polish processing in the metal membrane by the CMP method.
[Drawing 40] It is a sectional view for explaining the recess generated in polish processing in the metal membrane by the CMP method.
[Drawing 41] In polish processing, it generates in the metal membrane by the CMP method.
[Description of Notations]
1 [-- Controllers 55 and 71 / -- A slurry feeder, 81 / -- Electrolytic-solution feeder.] -- Polish equipment, 11 -- The processing head section, 61 -- An electrolysis power source, 55

[Translation done.]

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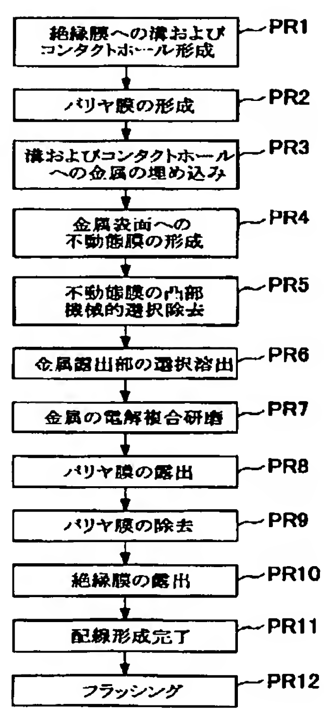
(54)【発明の名称】 半導体装置の製造方法、研磨装置および研磨方法

(57)【要約】
【課題】多層配線構造を有する半導体装置の配線を構成するための金属膜の研磨による平坦化工程において、ディッシング、エロージョンの発生を抑制可能な、研磨方法、研磨装置および半導体装置の製造方法を提供する。
【解決手段】金属膜の表面に当該金属の電解反応を妨げる作用を発揮する不動態膜を形成する工程（ＰＲ４）と、配線用溝の埋め込みによって生じた金属膜の表面に存在する凸部上の不動膜を機械研磨によって選択的に除去し、金属膜の凸部を表面に露出させる工程（ＰＲ５）と、露出した金属膜の凸部を電解研磨によって除去し、配線用溝の埋め込みによって生じた金属膜の表面の凹凸を平坦化する工程（ＰＲ６）と、表面が平坦化された金属膜の絶縁膜上に存在する金属膜を電解研磨と機械研磨とを複合させた電解複合研磨よって除去し、前記配線を形成する工程（ＰＲ７）を有する。



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【特許請求の範囲】

【請求項１】基板上に形成された絶縁膜に配線を形成するための配線用溝を形成する工程と、
前記配線用溝を埋め込むように、前記絶縁膜上に金属膜を堆積させる工程と、
前記絶縁膜上に堆積した金属膜の表面に当該金属膜の電解反応を妨げる作用を発揮する不動態膜を形成する工程と、
前記金属膜に形成された不動態膜のうち、前記配線用溝の埋め込みによって生じた前記金属膜の表面に存在する凸部上の不動膜を機械研磨によって選択的に除去し、当該金属の凸部を表面に露出させる工程と、
前記露出した金属膜の凸部を電解研磨によって除去し、前記配線用溝の埋め込みによって生じた前記金属膜の表面の凹凸を平坦化する工程とを有する半導体装置の製造方法。

【請求項２】前記表面が平坦化された金属膜の前記絶縁膜上に存在する余分な金属膜を電解研磨と機械研磨とを複合させた電解複合研磨よって除去し、前記配線を形成する工程をさらに有する請求項１に記載の半導体装置の製造方法。

【請求項３】前記電解複合研磨は、電解研磨と化学機械研磨とを複合させる請求項２に記載の半導体装置の製造方法。

【請求項４】前記配線用溝を形成した後に、前記絶縁膜上および前記溝内を覆うように前記金属膜の前記絶縁膜への拡散を防ぐための導電性材料からなるバリヤ膜を形成し、　前記露出した金属膜の凸部を平坦化した後に、
前記絶縁膜上に存在する余分な金属膜を前記電解複合研磨によって前記バリヤ膜が表面に露出するまで除去する工程と、
前記絶縁膜上に存在する余分なバリヤ膜を前記絶縁膜が表面に露出するまで前記電解複合研磨によって除去する工程とを有する請求項２に記載の半導体装置の製造方法。

【請求項５】導電性を有する研磨工具の研磨面と前記不動態膜との間に電解液を介在させ、前記金属膜およびバリヤ膜を陽極とし前記研磨工具を陰極として、前記金属膜およびバリヤ膜と前記研磨工具との間に電圧を印加し、
前記研磨工具を前記不動態膜の表面に相対的に移動させて、前記金属膜の凸部に形成された不動態膜を選択的に除去し、
前記選択的に除去された不動態膜から露出した前記金属膜の凸部を前記電解液の電解作用によって溶出させる請求項４に記載の半導体装置の製造方法。

【請求項６】前記研磨工具との間で電圧が印加された電極部材を前記金属膜およびバリヤ膜に接触または接近させて前記金属膜および前記バリヤ膜に通電し、
前記電極部材から前記前記金属膜および前記バリヤ膜を

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経由して前記研磨工具に流れる電流をモニタリングし、当該電流値の大きさに基づいて前記金属膜およびバリヤ膜の研磨の進行を管理する請求項５に記載の半導体装置の製造方法。

【請求項７】前記研磨工具との間で電圧が印加された電極部材を前記金属膜およびバリヤ膜に接触または接近させて前記金属膜および前記バリヤ膜に通電し、
前記電極部材と前記研磨工具との間に発生する電気抵抗の大きさをモニタリングし、当該電気抵抗値に基づいて前記金属膜およびバリヤ膜の研磨の進行を管理する請求項５に記載の半導体装置の製造方法。

【請求項８】前記研磨工具の研磨面と前記不動態膜との間に研磨砥粒を含む化学研磨剤を介在させて前記不動態膜を選択的に除去する請求項５に記載の半導体装置の製造方法。

【請求項９】前記金属膜と前記バリヤ膜とを構成する各材料に対してそれぞれ研磨レートの高い異なる化学研磨剤を用いて前記余分な金属膜とバリヤ膜とをそれぞれ除去する請求項５に記載の半導体装置の製造方法。

【請求項１０】前記余分なバリヤ膜を除去する工程では、前記バリヤ膜と前記研磨工具との間に印加する電圧を、前記余分な金属膜を除去する工程での前記金属膜と前記研磨工具との間に印加する電圧よりも低くする請求項５に記載の半導体装置の製造方法。

【請求項１１】前記配線用溝を形成する工程は、前記配線用溝の形成とともに、前記絶縁膜の下層に形成された不純物拡散層または配線と当該絶縁膜上に形成される配線とを接続するためのコンタクトホールを形成する工程を有し、
前記配線用溝に金属を埋め込む工程は、前記配線用溝とともに前記コンタクトホールに金属を埋め込む請求項２に記載の半導体装置の製造方法。

【請求項１２】前記配線の形成材料には、銅を使用し、前記配線用溝およびコンタクトホールには電気メッキ法を用いて銅を埋め込む請求項１１に記載の半導体装置の製造方法。

【請求項１３】前記バリヤ膜の形成材料には、Ｔａ、Ｔｉ、ＴａＮおよびＴｉＮのいずれかを用いる請求項４に記載の半導体装置の製造方法。

【請求項１４】前記不動態膜は、前記金属膜の表面を酸化させた酸化膜からなる請求項１に記載の半導体装置の製造方法。

【請求項１５】前記金属膜の表面に酸化剤を供給して前記酸化膜を形成する請求項１４に記載の半導体装置の製造方法。

【請求項１６】前記不動態膜は、前記金属膜を構成する金属の電解反応を妨げる作用を発揮する材料からなる膜を前記金属膜の表面上に形成する請求項１に記載の半導体装置の製造方法。

【請求項１７】前記不動態膜は、前記金属膜の表面に、

はっ水膜、油膜、酸化防止膜、界面活性剤からなる膜、キレート剤からなる膜、および、シランカップリング剤からなる膜のいずれかを形成する請求項１６に記載の半導体装置の製造方法。

【請求項１８】前記不動態膜は、前記金属膜よりも、電気的抵抗が高く、かつ、機械的強度が低い請求項１に記載の半導体装置の製造方法。

【請求項１９】研磨面を有し、導電性を有する研磨工具と、

前記研磨工具を所定の回転軸を中心に回転させ、かつ、保持する研磨工具回転保持手段と、

被研磨対象物を保持し所定の回転軸を中心に回転させる回転保持手段と、

前記研磨工具を前記被研磨対象物に対向する方向の目標位置に移動位置決めする移動位置決め手段と、

前記被研磨対象物の被研磨面と前記研磨工具の研磨面とを所定の平面に沿って相対移動させる相対移動手段と、

前記被研磨対象物の被研磨面上に電解液を供給する電解液供給手段と、

前記被研磨対象物の被研磨面を陽極とし前記研磨工具を陰極として、前記被研磨面から前記電解液を通じて前記研磨工具に流れる電解電流を供給する電解電流供給手段とを有する研磨装置。

【請求項２０】前記被研磨対象物の被研磨面に研磨砥粒を含む化学研磨剤を供給する研磨剤供給手段をさらに有する請求項１９に記載の研磨装置。

【請求項２１】前記電解電流供給手段は、前記被研磨対象物の被研磨面に接触可能または接近可能に配置され、前記被研磨対象物の被研磨面を陽極として当該被研磨面に通電する通電手段と、

前記通電手段と前記研磨工具との間に所定電位を印加する直流電源とを備える請求項１に記載の研磨装置。

【請求項２２】前記直流電源は、所定周期のパルス状の電圧を出力する請求項２１に記載の研磨装置。

【請求項２３】前記研磨工具は、ホイール状の導電性部材からなり、当該部材の環状の一端面が研磨面を構成しており、

前記通電手段は、前記研磨工具の内側に当該研磨工具と離隔して設けられ、前記回転保持手段によって保持され、前記研磨工具とともに回転する導電性の電極板を備える請求項２１に記載の研磨装置。

【請求項２４】前記電極板は、前記被研磨対象物の被研磨面に対向する側に当該被研磨面をスクラブする面を有するスクラブ部材を備える請求項２３に記載の研磨装置。

【請求項２５】前記スクラブ部材は、前記電解液および研磨砥粒を含む化学研磨剤を吸収し、かつ通過させることができる材料から形成されており、前記電極板側から供給される電解液および／または化学研磨剤を被研磨対象物の被研磨面に供給する請求項２４に記載の研磨装置。

【請求項２６】前記研磨工具は、前記回転保持手段に連結された導電性部材によって保持されており、前記回転する導電性部材に接触する通電ブラシを通じて通電される請求項２１に記載の研磨装置。

【請求項２７】前記電極部材は、前記被研磨対象物の被研磨面に形成された被電解金属に対して貴なる金属からなる請求項２３に記載の研磨装置。

【請求項２８】前記被研磨対象物の被研磨面から前記研磨工具に流れる電解電流の値を検出する電流検出手段をさらに備える請求項１９に記載の研磨装置。

【請求項２９】前記被研磨対象物の被研磨面を経由した前記電極部材と前記研磨工具との間の電気抵抗を検出する抵抗値検出手段を備える請求項２３に記載の研磨装置。

【請求項３０】前記電流検出手段の検出信号に基づいて、前記電解電流の値が一定となるように前記研磨工具と前記被研磨対象物との対向方向の位置を制御する制御手段をさらに有する請求項２９に記載の研磨装置。

【請求項３１】被研磨対象物の被研磨面の全面に回転しながら接触する研磨面を有する研磨工具を備え、前記被研磨対象物を前記研磨面に回転させながら接触させて平坦化研磨する研磨装置であって、

前記研磨面上に電解液を供給する電解液供給手段を有し、

前記研磨面に前記被研磨対象物の被研磨面に通電可能な陽極電極および陰極電極を備え、前記電解液による電解研磨と前記研磨面による機械研磨とを複合した電解複合研磨によって前記被研磨対象物の被研磨面を平坦化研磨する研磨装置。

【請求項３２】前記研磨面に研磨砥粒を含む化学研磨剤を供給する研磨剤供給手段をさらに有し、

前記電解液による電解研磨と前記研磨面および前記研磨剤による化学機械研磨とを複合した電解複合研磨によって前記被研磨対象物の被研磨面を平坦化研磨する請求項３１に記載の研磨装置。

【請求項３３】導電性の研磨工具の研磨面と金属膜が少なくとも表面または内層に形成された被研磨対象物の表面とを電解液を介在させて押し付け、

前記研磨工具を陰極とし前記被研磨対象物の表面を陽極として、前記被研磨対象物の表面から前記研磨工具に前記電解液を通じて流れる電解電流を供給し、

前記研磨工具と前記被研磨対象物とを共に回転させながら所定の平面に沿って相対移動させ、

前記電解液よる電解研磨および前記研磨面による機械研磨を複合した電解複合研磨によって前記被研磨対象物に形成された金属膜を平坦化する研磨方法。

【請求項３４】前記研磨面と前記被研磨対象物の表面との間に前記電解液とともに研磨砥粒を含む化学研磨剤を介在させ、前記電解液による電解研磨と前記研磨面およ

び前記研磨剤による化学機械研磨とを複合した電解複合研磨によって前記被研磨対象物に形成された金属膜を平坦化する請求項３３に記載の研磨方法。

【請求項３５】前記被研磨対象物には、異なる材料からなる複数の膜が積層されており、
前記各膜の材料の電気的特性の違いによって変化する前記電解液を通じて前記被研磨対象物の表面から前記研磨工具に流れる電解電流をモニタリングし、当該電解電流の大きさに基づいて研磨の進行を管理する請求項３３に記載の研磨方法。

【請求項３６】前記研磨工具と前記被研磨対象物の表面との間に、所定の周期のパルス状の電圧を印加して前記電解電流を供給する請求項３３に記載の研磨方法。

【請求項３７】電極部材を前記電解液が供給された前記被研磨対象物の表面に接近または当接させ、前記被研磨対象物の表面へ通電する請求項３３に記載の研磨方法。

【請求項３８】前記電極部材を前記研磨工具とともに回転させ、かつ、前記被研磨対象物に対して相対移動させながら前記被研磨対象物に形成された金属膜に通電する請求項３７に記載の研磨方法。

【請求項３９】前記被研磨対象物の表面を経由した前記電極部材と前記研磨工具との間の電気抵抗の大きさに基づいて、前記被研磨対象物の研磨の進行を管理する請求項３７に記載の研磨方法。

【請求項４０】前記研磨剤に含まれる研磨砥粒を正に帯電させる請求項３４に記載の研磨方法。

【請求項４１】被研磨対象物に形成された金属膜の表面に当該金属膜の電解反応を妨げる作用を発揮する不動態膜を形成する工程と、
導電性の研磨工具の研磨面と前記金属膜との間に電解液を介在させて当該研磨面と金属膜とを押し付け、かつ、前記研磨工具と前記金属膜と間に所定の電圧を印加する工程と、
前記研磨工具の研磨面と前記被研磨対象物の金属膜とを所定の平面に沿って相対移動させ、前記金属膜のうち前記研磨工具の研磨面に対して突出した凸部上の不動態膜を前記研磨工具の機械研磨によって選択的に除去する工程と、
前記不動態膜が除去されて表面に露出した金属膜の凸部を前記電解液による電解研磨作用によって除去して前記金属膜を平坦化する工程とを有する研磨方法。

【請求項４２】前記研磨面と前記金属膜との間に前記電解液とともに研磨砥粒を含む化学研磨剤を介在させ、前記研磨面および前記研磨砥粒による化学機械研磨によって前記不動態膜を選択的に除去する請求項４１に記載の研磨方法。

【請求項４３】前記不動態膜は、前記金属膜の表面を酸化させた酸化膜からなる請求項４１に記載の研磨方法。

【請求項４４】前記不動態膜は、前記金属膜を構成する金属の電解反応を妨げる作用を発揮する材料からなる膜を前記金属膜の表面上に形成する請求項４１に記載の研磨方法。

【請求項４５】前記不動態膜は、前記金属膜よりも、電気的抵抗が高く、かつ、機械的強度が低い請求項４１に記載の研磨方法。

【請求項４６】電極部材を前記金属膜の表面に接近または当接させ、前記金属膜へ通電する請求項４１に記載の研磨方法。

【請求項４７】前記電極部材と前記研磨工具との間の電気抵抗の大きさに基づいて研磨の進行を管理する請求項４６に記載の研磨方法。

【請求項４８】前記研磨剤に含まれる研磨砥粒を正に帯電させる請求項４２に記載の研磨方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、たとえば、半導体装置の多層配線構造に伴う凹凸面を平坦化する研磨装置および研磨方法と多層配線構造をもつ半導体装置の製造方法に関する。

【０００２】

【従来の技術】半導体装置の高集積化、小型化に伴い、配線の微細化、配線ピッチの縮小化、配線の多層化が進んでおり、半導体装置の製造プロセスにおける多層配線技術の重要性が増大している。一方、従来、多層配線構造の半導体装置の配線材料としてアルミニウム（Ａｌ）が多用されてきたが、最近の０．２５μｍルール以下のデザインルールにおいて、信号の伝搬遅延を抑制するために、配線材料をアルミニウム（Ａｌ）から銅（Ｃｕ）に代えた配線プロセスの開発が盛んに行われている。Ｃｕを配線に使用すると、低抵抗と高エレクトロマイグレーション耐性を両立できるというメリットがある。このＣｕを配線に使用したプロセスでは、たとえば、あらかじめ層間絶縁膜に形成した溝状の配線パターンに金属を埋め込み、ＣＭＰ(Chemical Mechanical Polishing: 化学機械研磨) 法によって余分な金属膜を除去して配線を形成する、ダマシン(damascene) 法とよばれる配線プロセスが有力となっている。このダマシン法は、配線のエッチングが不要となり、さらに上の層間絶縁膜も自ずと平坦なものとなるので、工程を簡略化できるという特徴を有する。さらに、層間絶縁膜に配線だけでなく、コンタクトホールも溝として開け、配線とコンタクトホールを同時に金属で埋め込むデュアルダマシン(dual damascene)法では、さらに大幅な配線工程の削減が可能となる。

【０００３】ここで、上記のデュアルダマシン法による配線形成プロセスの一例について図３２～図３７を参照して説明する。なお、配線材料としてＣｕを用いた場合について説明する。まず、図３２に示すように、たとえば、図示しない不純物拡散領域が適宜形成されているシリコン等の半導体からなる基板３０１上に、たとえば、

シリコン酸化膜からなる層間絶縁膜３０２を、たとえば、減圧ＣＶＤ(Chemical Vapour Deposition)法により形成する。次いで、図３３に示すように、基板３０１の不純物拡散領域に通じるコンタクトホール３０３および基板３０１の不純物拡散領域と電気的に接続される所定パターンの配線が形成される溝３０４を公知のフォトリソグラフィ技術およびエッチング技術を用いて形成する。次いで、図３４に示すように、バリヤ膜３０５を層間絶縁膜３０２の表面およびコンタクトホール３０３、溝３０４内に形成する。このバリヤ膜３０５は、たとえば、Ｔａ、Ｔｉ、ＴａＮ、ＴｉＮ等の材料を公知のスパッタ法により形成する。バリヤ膜３０５は、配線を構成する材料が層間絶縁膜３０２中に拡散するのを防止するために設けられる。特に、配線材料がＣｕで層間絶縁膜３０２がシリコン酸化膜のような場合には、Ｃｕはシリコン酸化膜への拡散係数が大きく、酸化されやすいため、これを防止する。

【０００４】次いで、図３５に示すように、バリヤ膜３０５上に、シードＣｕ膜３０６を公知のスパッタ法により所定の膜厚で形成し、次いで、図３６に示すように、コンタクトホール３０３および溝３０４をＣｕで埋め込むように、Ｃｕ膜３０７を形成する。Ｃｕ膜３０７は、たとえば、メッキ法、ＣＶＤ法、スパッタ法等によって形成する。次いで、図３７に示すように、層間絶縁膜３０２上の余分なＣｕ膜３０７およびバリヤ膜３０５をＣＭＰ法によって除去し、平坦化する。これによって、配線３０８およびコンタクト３０９とが形成される。上記したプロセスを配線３０８上で繰り返し行うことにより、多層配線を形成することができる。

【０００５】

【発明が解決しようとする課題】ところで、上記したデュアルダマシン法を用いた多層配線形成プロセスでは、余分なＣｕ膜３０７およびバリヤ膜３０５をＣＭＰ法によって除去する工程において、層間絶縁膜３０２とＣｕ膜３０７およびバリヤ膜３０５との除去性能が異なることから、配線３０８にディッシング、エロージョン（シンニング）、リセス等が発生しやすいという不利益が存在した。ディッシングは、図３８に示すように、たとえば、０．１８μｍルールのデザインルールにおいて、たとえば、１００μｍ程度のような幅の広い配線３０８が存在した場合に、当該配線の中央部が過剰に除去されへこんでしまう現象であり、このディッシングが発生すると配線３０８の断面積が不足するため、配線抵抗値不良等の原因となる。このディッシングは、配線材料に比較的軟質の銅やアルミニウムを用いた場合に発生しやすい。エロージョンは、図３９に示すように、たとえば、３０００μｍの範囲に１．０μｍの幅の配線が５０パーセントの密度で形成されているようなパターン密度の高い部分が過剰に除去されてしまう現象であり、エロージョンが発生すると配線の断面積が不足するため、配線抵抗値不良等の原因となる。リセスは、図４０に示すように、層間絶縁膜３０２と配線３０８との境界で配線３０８が低くなり段差ができてしまう現象であり、この場合にも配線の断面積が不足するため、配線抵抗値不良等の原因となる。さらに、余分なＣｕ膜３０７およびバリヤ膜３０５をＣＭＰ法によって除去する工程では、Ｃｕ膜３０７およびバリヤ膜３０５を効率的に除去する必要があり、単位時間当たりの除去量である研磨レートは、たとえば、５００ｎｍ／ｍｉｎ以上となるように要求されている。この研磨レートを稼ぐためにはウェーハに対する加工圧力を大きくする必要があり、加工圧力を大きくすると、図４１に示すように、配線表面にスクラッチＳＣやケミカルダメージＣＤが発生しやすくなり、特に、軟質のＣｕやアルミニウムでは発生しやすい。このため、配線のオープン、ショート、配線抵抗値不良等の不具合の原因となり、また、加工圧力を大きくすると、上記のディッシング、エロージョン、リセスの発生量も大きくなるという不利益が存在した。

【０００６】本発明は、上記した問題に鑑みてなされたものであって、たとえば、多層配線構造を有する半導体装置の配線等の金属膜を研磨によって平坦化する際に、初期凹凸を容易に平坦化でき、かつ余分な金属膜の除去効率に優れ、ディッシング、エロージョン等の金属膜の過剰な除去の発生を抑制可能な研磨装置および研磨方法、半導体装置の製造方法を提供する。

【０００７】

【課題を解決するための手段】本発明の研磨装置は、研磨面を有し、導電性を有する研磨工具と、前記研磨工具を所定の回転軸を中心に回転させ、かつ、保持する研磨工具回転保持手段と、被研磨対象物を保持し所定の回転軸を中心に回転させる回転保持手段と、前記研磨工具を前記被研磨対象物に対向する方向の目標位置に移動位置決めする移動位置決め手段と、前記被研磨対象物の被研磨面と前記研磨工具の研磨面とを所定の平面に沿って相対移動させる相対移動手段と、前記被研磨対象物の被研磨面上に電解液を供給する電解液供給手段と、前記被研磨対象物の被研磨面を陽極とし前記研磨工具を陰極として、前記被研磨面から前記電解液を通じて前記研磨工具に流れる電解電流を供給する電解電流供給手段とを有する。

【０００８】また、本発明の研磨装置は、被研磨対象物の被研磨面の全面に回転しながら接触する研磨面を有する研磨工具を備え、前記被研磨対象物を前記研磨面に回転させながら接触させて平坦化研磨する研磨装置であって、前記研磨面上に電解液を供給する電解液供給手段を有し、前記研磨面に前記被研磨対象物の被研磨面に通電可能な陽極電極および陰極電極を備え、前記電解液による電解研磨と前記研磨面による機械研磨とを複合した電解複合研磨によって前記被研磨対象物の被研磨面を平坦化研磨する。

【０００９】本発明の研磨方法は、導電性の研磨工具の研磨面と金属膜が少なくとも表面または内層に形成された被研磨対象物の表面とを電解液を介在させて押し付け、前記研磨工具を陰極とし前記被研磨対象物の表面を陽極として、前記被研磨対象物の表面から前記研磨工具に前記電解液を通じて流れる電解電流を供給し、前記研磨工具と前記被研磨対象物とを共に回転させながら所定の平面に沿って相対移動させ、前記電解液よる電解研磨および前記研磨面による機械研磨を複合した電解複合研磨によって前記被研磨対象物に形成された金属膜を平坦化する。

【００１０】また、本発明の研磨方法は、被研磨対象物に形成された金属膜の表面に当該金属膜の電解反応を妨げる作用を発揮する不動態膜を形成する工程と、導電性の研磨工具の研磨面と前記金属膜との間に電解液を介在させて当該研磨面と金属膜とを押し付け、かつ：前記研磨工具と前記金属膜と間に所定の電圧を印加する工程と、前記研磨工具の研磨面と前記被研磨対象物の金属膜とを所定の平面に沿って相対移動させ、前記金属膜のうち前記研磨工具の研磨面に対して突出した凸部上の不動態膜を前記研磨工具の機械研磨によって選択的に除去する工程と、前記不動態膜が除去されて表面に露出した金属膜の凸部を前記電解液による電解研磨作用によって除去して前記金属膜を平坦化する工程とを有する。

【００１１】本発明の半導体装置の製造方法は、基板上に形成された絶縁膜に配線を形成するための配線用溝を形成する工程と、前記配線用溝を埋め込むように、前記絶縁膜上に金属膜を堆積させる工程と、前記絶縁膜上に堆積した金属膜の表面に当該金属膜の電解反応を妨げる作用を発揮する不動態膜を形成する工程と、前記金属膜に形成された不動態膜のうち、前記配線用溝の埋め込みによって生じた前記金属膜の表面に存在する凸部上の不動膜を機械研磨によって選択的に除去し、当該金属の凸部を表面に露出させる工程と、前記露出した金属膜の凸部を電解研磨によって除去し、前記配線用溝の埋め込みによって生じた前記金属膜の表面の凹凸を平坦化する工程とを有する。

【００１２】また、本発明の半導体装置の製造方法は、前記表面が平坦化された金属膜の前記絶縁膜上に存在する余分な金属膜を電解研磨と機械研磨とを複合させた電解複合研磨よって除去し、前記配線を形成する工程をさらに有する。

【００１３】本発明の半導体装置の製造方法では、表面に凹凸がある金属膜に不動態膜を形成し、不動態膜を機械的に除去することで、金属膜の凸部が表面に露出する。この金属膜の凸部は残った不動態膜をマスクとして電解液による電解作用によって選択的に溶出する。この結果、金属膜の初期凹凸が平坦化される。また、初期凹凸が平坦化された金属膜は、電解複合研磨によって高能率に除去され、たとえば、配線を形成する際に絶縁膜上に存在する余分な金属膜は高能率に除去される。余分な金属膜が除去されて絶縁膜が露出すると、自動的にその部分の電解作用が停止し、絶縁膜に形成された配線用溝に埋め込まれた金属膜が過剰に除去されない。

【００１４】

【発明の実施の形態】以下、本発明の実施の形態について図面を参照して説明する。

<u>研磨装置の構成</u>

図１は、本発明の一実施形態に係る研磨装置の構成を示す図である。図２は図１に示す研磨装置の加工ヘッド部の要部拡大図である。図１に示す研磨装置１は、加工ヘッド部２と、電解電源６１と、研磨装置１全体を制御する機能を有するコントローラ５５と、スラリー供給装置７１と、電解液供給装置８１とを備えている。なお、図示しないが、研磨装置１は、クリーンルーム内に設置され：当該クリーンルーム内には被研磨対象物としてのウェーハを収容したウェーハカセットを搬出入する搬出入ポートが設けられている。さらに、この搬出入ポートを通じてクリーンルーム内に搬入されたウェーハカセットと研磨装置１との間でウェーハの受け渡しを行うウェーハ搬送ロボットが搬出入ポートと研磨装置１との間に設置される。

【００１５】加工ヘッド部２は、研磨工具３を保持し回転させ、研磨工具３を保持する研磨工具保持部１１と、研磨工具保持部１１をZ軸方向の目標位置に位置決めするZ軸位置決め機構部３１と、被研磨対象物としてのウェハWを保持し回転させX軸方向に移動するX軸移動機構部４１とを備える。なお、研磨工具保持部１１が本発明の研磨工具回転保持手段の一具体例に対応しており、X軸移動機構部４１が本発明の回転保持手段および相対移動手段の一具体例に対応しており、Z軸位置決め機構部３１は本発明の移動位置決め手段の一具体例に対応している。

【００１６】Z軸位置決め機構部３１は、図示しないコラムに固定されたZ軸サーボモータ１８と、保持装置１２および主軸モータ１３に連結され、Z軸サーボモータ１８に接続されたボールネジ軸１８aに螺合するネジ部が形成されたZ軸スライダ１６と、Z軸スライダ１６をZ軸方向に移動自在に保持する図示しないコラムに設置されたガイドレール１７とを有する。

【００１７】Z軸サーボモータ１８は、Z軸サーボモータ１８に接続されたZ軸ドライバ５２から駆動電流が供給されて回転駆動される。ボールネジ軸１８aは、Z軸方向方向に沿って設けられ、一端がZ軸サーボモータ１８に接続され、他端は、上記の図示しないコラムに設けられた保持部材によって回転自在に保持されている。これにより、Z軸位置決め機構部３１は、Z軸サーボモータ１８の駆動によって、研磨工具保持部１１に保持された研磨工具３をZ軸方向の任意の位置に移動位置決めする。Z軸位置決め機構部３１の位置決め精度は、たとえ

ば、分解能０．１μm程度としている。

【００１８】Ｘ軸移動機構４１は、ウェハWをチャキングするウェハテーブル４２と、ウェハテーブル４２を回転自在に保持する保持装置４５と、ウェハテーブル４２を回転させる駆動力を供給する駆動モータ４４と、駆動モータ４４と保持装置４５の回転軸とを連結するベルト４６と、保持装置４５に設けられた加工パン４７と、駆動モータ４４および保持装置４５が設置されたX軸スライダ４８と、図示しない架台に基台されたX軸サーボモータ４９と、X軸サーボモータ４９に接続されたボールネジ軸４９ａと、X軸スライダ４８に連結されボールネジ軸４９ａに螺合するネジ部が形成された可動部材４９ｂとを有する。

【００１９】ウェハテーブル４２は、たとえば、真空吸着手段によってウェハWを吸着する。加工パン４７は、使用済の電解液や、スラリー等の液体を回収するために設けられている。駆動モータ４４は、テーブルドライバ５３から駆動電流が供給されることによって駆動され、この駆動電流を制御することでウェハテーブル４２を所定の回転数で回転させることができる。X軸サーボモータ４９は、X軸サーボモータ４９に接続されたX軸ドライバ５４から供給される駆動電流によって回転駆動し、X軸スライダ４８がボールネジ軸４９ａおよび可動部材４９ｂを介してX軸方向に駆動する。このとき、X軸サーボモータ４９に供給する駆動電流を制御することによって、ウェーハテーブル４２のX軸方向の速度制御が可能となる。

【００２０】図２は、研磨工具保持部１１の内部構造の一例を示す図である。研磨工具保持部１１は、研磨工具３と、研磨工具３を保持するフランジ部材４と、フランジ部材４を回転自在に保持する保持装置１２と、保持装置１２に保持された主軸１２ａと接続され当該主軸１２ａを回転させる主軸モータ１３と、主軸モータ１３上に設けられたシリンダ装置１４とを備える。

【００２１】主軸モータ１３は、たとえば、ダイレクトドライブモータからなり、このダイレクトドライブモータの図示しないロータは、保持装置１２に保持された主軸１２ａに連結されている。また、主軸モータ１３は中心部にシリンダ装置１４のピストンロッド１４ｂが挿入される貫通孔を有している。主軸モータ１３は、主軸ドライバ５１から供給される駆動電流によって駆動される。

【００２２】保持装置１２は、たとえば、エアベアリングを備えており、このエアベアリングで主軸１２ａを回転自在に保持している。保持装置１２の主軸１２ａも中心部にシリンダ装置１４のピストンロッド１４ｂが挿入される貫通孔を有している。

【００２３】フランジ部材４は、金属材料から形成されており、保持装置１２の主軸１２ａに連結され、底部に開口部４ａを備え、下端面４ｂに研磨工具３が固着されている。フランジ部材４の上端面４ｃ側は保持装置１２に保持された主軸１２ａに連結されており、主軸１２ａの回転によってフランジ部材４も回転する。フランジ部材４の上端面４ｃは、主軸モータ１３および保持装置１２の側面に設けられた導電性の通電部材２８に固定された通電ブラシ２７と接触しており、通電ブラシ２７とフランジ部材４とは電気的に接続されている。

【００２４】シリンダ装置１４は、主軸モータ１３のケース上に固定されており、ピストン１４ａを内蔵しており、ピストン１４ａは、たとえば、シリンダ装置１４内に供給される空気圧によって矢印Ａ１およびＡ２のいずれかの向きに駆動される。このピストン１４ａには、ピストンロッド１４ｂが連結されており、ピストンロッド１４ｂは、主軸モータ１３および保持装置１２の中心を通って、フランジ部材４の開口部４ａから突き出ている。ピストンロッド１４ｂの先端には、押圧部材２１が連結されており、この押圧部材２１はピストンロッド１４ｂに対して所定の範囲で姿勢変更が可能な連結機構によって連結されている。押圧部材２１は、対向する位置に配置された絶縁板２２の開口２２ａの周縁部に当接可能となっており、ピストンロッド１４ｂの矢印Ａ２方向への駆動によって絶縁板２２を押圧する。

【００２５】シリンダ装置１４のピストンロッド１４ｂの中心部には、貫通孔が形成されており、貫通孔内に通電軸２０が挿入され、ピストンロッド１４ｂに対して固定されている。通電軸２０は、導電性材料から形成されており、上端側はシリンダ装置１４のピストン１４ａを貫通してシリンダ装置１４上に設けられたロータリジョイント１５まで伸びており、下端側は、ピストンロッド１４ｂおよび押圧部材２１を貫通して電極板２３まで伸びており、電極板２３に接続されている。

【００２６】通電軸２０は、中心部に貫通孔が形成されており、この貫通孔が化学研磨剤（スラリー）および電解液をウェーハW上に供給する供給ノズルとなっている。また、通電軸２０は、ロータリジョイント１５と、電極板２３とを電気的に接続する役割を果たしている。

【００２７】通電軸２０の上端部に接続されたロータリジョイント１５は、電解電極６１のプラス極と電気的に接続されており、このロータリジョイント１５は通電軸２０が回転しても通電軸２０への通電を維持する。すなわち、通電軸２０は回転してもロータリジョイント１５によって電解電極６１からプラスの電位が印加される。

【００２８】通電軸２０の下端部に接続された電極板２３は、金属材料からなり、特に、ウェーハWに形成される金属膜より貴なる金属で形成されている。電極板２３は、上面側が絶縁板２２に保持されており、電極板２３の外周部は絶縁板２２に嵌合しており、下面側にはスクラブ部材２４が貼着されている。

【００２９】ここで、図３（ａ）は電極板２３の構造の一例を示す下面図であり、図３（ｂ）は電極板２３と、

通電軸２０、スクラブ部材２４および絶縁部材４との位置関係を示す断面図である。図３（ａ）に示すように、電極板２３の中央部には円形の開口部２３ａが設けられており、この開口部２３ａを中心に電極板２３の半径方向に放射状に伸びる複数の溝部２３ｂが形成されている。また、図３（ｂ）に示すように、電極板２３の開口部２３ａには、通電軸２０の下端部が嵌合固着されている。このような構成とすることで、通電軸２０の中心部に形成された供給ノズル２０ａを通じて供給されるスラリーおよび電解液が溝部２３ｂを通じてスクラブ部材２４の全面に拡散するようになっている。すなわち、電極板２３と、通電軸２０、スクラブ部材２４および絶縁部材４が回転しながら、スラリーおよび電解液が通電軸２０の中心部に形成された供給ノズル２０ａを通じてスクラブ部材２４の上側面に供給されると、スクラブ部材２４の上側面全体にスラリーおよび電解液が広がる。なお、スクラブ部材２４および通電軸２０の供給ノズル２０ａが本発明の研磨剤供給手段および電解液供給手段の一具体例に対応している。また、電極板２３、通電軸２０およびロータリジョイント１５が本発明の通電手段の一具体例に対応している。

【００３０】電極板２３の下面に貼着されたスクラブ部材２４は、電解液およびスラリーを吸収し、これらを上側面から下側面に通過させることができる材料から形成されている。また、このスクラブ部材２４は、ウェーハWに対向する面がウェーハWに接触してウェーハWをスクラブする面となっており、ウェーハW表面にスクラッチ等を発生させないように、たとえば、柔らかいブラシ状の材料、スポンジ状の材料、多孔質状の材料等から形成される。たとえば、ウレタン樹脂、メラミン樹脂、エポキシ樹脂、ポリビニルアセタール（ＰＶＡ）などの樹脂からなる多孔質体が挙げられる。

【００３１】絶縁板２２は、たとえば、セラミクス等の絶縁材料から形成されており、この絶縁板２２は複数の棒状の連結部材２６によって保持装置１２の主軸１２ａに連結されている。連結部材２６は、絶縁板２２の中心軸から所定の半径位置に等間隔に配置されており、保持装置１２の主軸１２ａに対して移動自在に保持されている。このため、絶縁板２２は主軸１２ａの軸方向に移動可能である。また、絶縁板２２と主軸１２ａとの間には、各連結部材２６に対応して、たとえば、コイルスプリングからなる弾性部材２５で接続されている。

【００３２】絶縁板２２を保持装置１２の主軸１２ａに対して移動自在にし、絶縁板２２と主軸１２ａとを弾性部材２５で連結する構成とすることにより、シリンダ装置１４に高圧エアを供給してピストンロッド１４ｂを矢印Ａ２の向きに下降させると、押圧部材２１が弾性部材２５の復元力に逆らって絶縁板２２を下方に押し下げ、これとともにスクラブ部材２４も下降する。この状態からシリンダ装置１４への高圧エアの供給を停止すると、弾性部材２５の復元力によって、絶縁板２２は上昇し、これとともにスクラブ部材２４も上昇する。

【００３３】研磨工具３は、フランジ部材４の環状の下端面４ｂに固着されている。この研磨工具３は、ホイール状に形成されており、下端面に環状の研磨面３ａを備えている。研磨工具３は、導電性を有しており、好ましくは、比較的軟質性の材料で形成する。たとえば、バインダマトリクス（結合剤）自体が導電性を持つカーボンや、あるいは、焼結銅、メタルコンパウンド等の導電性材料を含有するウレタン樹脂、メラミン樹脂、エポキシ樹脂、ポリビニルアセタール（ＰＶＡ）などの樹脂からなる多孔質体から形成することができる。研磨工具３は、導電性を有するフランジ部材４に直接接続され、フランジ部材４に接触する通電ブラシ２７から通電される。すなわち、主軸モータ１３および保持装置１２の側面に設けられた導電性の通電部材２８は、電解電源６１のマイナス極と電気的に接続され、通電部材２８に設けられた通電ブラシ２７はフランジ部材４の上端面４ｃに接触しており、これにより、研磨工具３は電解電源６１と通電部材２８、通電ブラシ２７およびフランジ部材４を介して電気的に接続されている。

【００３４】研磨工具３は、たとえば、図４に示すように、研磨面３ａは中心軸に対して微小な角度で傾斜している。また、保持部材１２の主軸１２ａもウェーハWの主面に対して研磨面３ａの傾斜と同様に傾斜している。たとえば、保持部材１２のZ軸スライダ１６への取り付け姿勢を調整することで主軸１２ａの微小な傾斜をつくり出すことができる。このように、研磨工具３の中心軸がウェーハWの主面に対して微小角度で傾斜していることにより、研磨工具３の研磨面３ａを所定の加工圧力ＦでウェーハWに押し付けた際に、研磨面３ａのウェーハWに対する実効的な作用領域Ｓが図４に示すように、研磨工具３の半径方向に伸びる直線状の領域となる。このため、ウェーハWを研磨工具３に対してＸ軸方向に移動させて研磨下降を行う際に、図５（ａ）の状態から図５（ｂ）に移動する間、実効的な作用領域Ｓの面積は略一定となる。本実施形態に係る研磨装置１では、研磨工具３の研磨面３ａの一部を部分的にウェーハWの表面に作用させ、実効的作用領域ＳをウェーハWの表面に均一に走査させてウェーハWの全面を均一に研磨する。

【００３５】電解電源６１は、上記したロータリジョイント１５と通電ブラシ１２との間に所定の電圧を印加する装置である。ロータリジョイント１５と通電ブラシ１２との間に電圧を印加することによって、研磨工具３とスクラブ部材２４との間には電位差が発生する。電解電源６１には、常に一定の電圧を出力する定電圧電源ではなく、好ましくは、電圧を一定周期でパルス状に出力する、たとえば、スイッチング・レギュレータ回路を内蔵した直流電源を使用する。具体的には、パルス状の電圧を一定周期で出力し、パルス幅を適宜変更可能な電源を

使用する。一例としては、出力電圧がＤＣ１５０Ｖ、最大出力電流が２～３Ａ、パルス幅が１，２，５，１０，２０，５０μｓのいずれかに変更可能なものを使用した。上記のような幅が短いパルス状の電圧出力とするのは、１パルス当たりの電解溶出量を非常に小さくするためである。すなわち、ウェーハWの表面に形成された金属膜の凹凸や接触した場合などにみられる極間距離の急変による放電、気泡やパーティクルなどが介在した場合におこる電気抵抗の急変によるスパーク放電など、金属膜の突発的なクレータ状の巨大溶出を防止、あるいは、できる限り抑制する小さなものの連続にするために有効である。また、出力電流に比して出力電圧が比較的高いため、極間距離の設定にある程度のマージンを設定する事ができる。すなわち、極間距離が多少変わっても出力電圧が高いため電流値変化は小さい。

【００３６】電解電源６１には、本発明の電流検出手段としての電流計６２を備えており、この電流計６２は、電解電源６１に流れる電解電流をモニタするために設けられており、モニタした電流値信号６２ｓをコントローラ５５に出力する。また、電解電源６１は、本発明の抵抗値検出手段としての抵抗計６３を備えており、この抵抗計６３は電解電源６１に流れる電流に基づいて、ウェーハWの表面を経由した研磨工具３と電極板２３との間の電気抵抗をモニタリングするために設けられており、モニタリングした電気抵抗値信号６３ｓをコントーラ５５に出力する。

【００３７】スラリー供給装置７１は、スラリーを上記の通電軸２０の供給ノズル２０ａに供給する。スラリーとしては、金属膜の研磨用として、たとえば、過酸化水素、硝酸鉄、ヨウ素酸カリウム等をベースとした酸化力のある水溶液に酸化アルミニウム（アルミナ）、酸化セリウム、シリカ、酸化ゲルマニウム等を研磨砥粒として含有させたものを使用する。また、研磨砥粒は、分散性を良くしてコロイド状態を保持するために予め正に帯電させておく。

【００３８】電解液供給装置８１は、電解液ＥＬを加工ヘッド部１１に供給する。電解液ＥＬは、溶媒とイオン的に分離した溶質とからなる溶液である。この電解液として、たとえば、硝酸塩あるいは塩化物系に還元剤を調整した水溶液を使用することができる。

【００３９】コントローラ５５は、研磨装置１の全体を制御する機能を有し、具体的には、主軸ドライバ５１に対して制御信号５１ｓを出力して研磨工具３の回転数を制御し、Ｚ軸ドライバ５２に対して制御信号５２ｓを出力して研磨工具３のＺ軸方向の位置決め制御を行い、テーブルドライバ５３に対して制御信号５３ｓを出力してウェーハWの回転数を制御し、Ｘ軸ドライバ５４に対して制御信号５４ｓを出力して、ウェーハWのＸ軸方向の速度制御を行う。また、コントローラ５５は、電解液供給装置８１およびスラリー供給装置７１の動作を制御し、加工ヘッド部２への電解液ＥＬおよびスラリーＳＬの供給動作を制御する。

【００４０】また、コントローラ５５は、電解電源６１の出力電圧、出力パルスの周波数、出力パルスの幅等を制御可能となっている。また、コントローラ５５には、電解電源６１の電流計６２および抵抗計６３からの電流値信号６２ｓおよび電気抵抗値信号６３ｓが入力される。コントローラ５５は、これら電流値信号６２ｓおよび電気抵抗値信号６３ｓに基づいて、研磨装置１の動作を制御可能となっている。具体的には、電流値信号６２ｓから得られた電解電流が一定となるように、電流値信号６２ｓをフィードバック信号としてＺ軸サーボモータ１８の制御したり、電流値信号６２ｓまたは電気抵抗値信号６３ｓで特定される電流値、電気抵抗値の値に基づいて、研磨加工を停止させるように研磨装置１の動作を制御する。

【００４１】コントローラ５５に接続されたコントロールパネル５６は、オペレータが各種のデータを入力したり、たとえば、モニタリングした電流値信号６２ｓおよび電気抵抗値信号６３ｓを表示したりする。

【００４２】次に、上記した研磨装置１による研磨動作をウェーハW表面に形成された金属膜を研磨する場合を例に説明する。なお、ウェーハWの表面には、たとえば、銅からなる金属膜が形成されている場合について説明する。まず、ウェーハテーブル４５にウェーハWをチャッキングし、ウェーハテーブル４５を駆動して所定の回転数でウェーハWを回転させる。また、ウェーハテーブル４５をＸ軸方向に移動して、フランジ部４に取り付けられた研磨工具３をウェーハWの上方の所定位置に位置させ、研磨工具３を所定の回転数で回転させる。研磨工具３を回転させると、フランジ部４に連結された絶縁板２２、電極板２３およびスクラブ部材２４も回転駆動される。また、スクラブ部材２４を押圧している押圧部材２１、ピストンロッド１４ｂ、ピストン１４ａ、通電軸２０も同時に回転する。

【００４３】この状態から、スラリー供給装置７１および電解液供給装置８１からそれぞれスラリーＳＬおよび電解液ＥＬを通電軸２０内の供給ノズル２０ａに供給すると、スクラブ部材２４の全面からスラリーＳＬおよび電解液ＥＬが供給される。研磨工具３をＺ軸方向に下降させて研磨工具３の研磨面３ａをウェーハWの表面に接触させ、所定の加工圧力で押圧させる。また、電解電源６１を起動させて、通電ブラシ２７を通じて研磨工具３にマイナスの電位を印加し、ロータリジョイント１５を通じてスクラブ部材２４にプラスの電位を印加する。

【００４４】さらに、シリンダ装置１４に高圧エアを供給して、図１の矢印Ａ２の方向にピストンロッド１４ｂを下降させ、スクラブ部材２４の下面をウェーハWに接触あるいは接近する位置まで移動させる。この状態からウェーハテーブル４５をＸ軸方向に所定の速度パターン

で移動させ、ウェーハWの全面を一様に研磨加工する。

【００４５】ここで、図６は、研磨装置１において研磨工具３をＺ軸方向に下降させ、ウェーハWの表面に接触させた状態を示す概略図であり、図７は図６の円Ｃ内の拡大図であり、図８は図７の円Ｄ内の拡大図である。図７に示すように、スクラブ部材２４はウェーハWに形成された金属膜ＭＴに、ウェーハW上に供給された電解液ＥＬを介して、または、直接接触することにより陽極として通電し、研磨工具３もウェーハWに形成された金属膜ＭＴに、ウェーハW上に供給された電解液ＥＬを介して、または、直接接触することにより陰極として通電する。なお、図７に示すように、金属膜ＭＴとスクラブ部材２４との間には、ギャップδｂが存在している。さらに、図８に示すように、金属膜ＭＴと研磨工具３の研磨面３ａとの間にはギャップδｗが存在している。図７に示すように、絶縁板４は、研磨工具３とスクラブ部材２４（電極板２３）との間に介在しているが、絶縁板４の抵抗Ｒ０は非常に大きく、したがって、スクラブ部材２４から絶縁板４を介して研磨工具３に流れる電流i_0はほぼ零であり、スクラブ部材２４から絶縁板４を介して研磨工具３には電流が流れない。

【００４６】このため、スクラブ部材２４から研磨工具３に流れる電流は、直接電解液ＥＬ中の抵抗Ｒ１を経由して研磨工具３に流れる電流i_1と、電解液ＥＬ中からウェーハWの表面に形成された銅からなる金属膜ＭＴを経由して再度電解液ＥＬ中を通って研磨工具３に流れる電流中に流れる電流ｉ２に分岐する。金属膜ＭＴの表面に電流ｉ２が流れると、金属膜ＭＴを構成する銅は、電解液ＥＬの電解作用によってイオン化し、電解液ＥＬ中に溶出する。

【００４７】ここで、電解液ＥＬ中の抵抗Ｒ１は、陽極としてのスクラブ部材２４と陰極としての研磨工具３との距離ｄに比例して極端に大きくなる。このため、極間距離ｄを、ギャップδｂおよびギャップδｗよりも十分に大きくしておくことで、直接電解液ＥＬ中の抵抗Ｒ１を経由して研磨工具３に流れる電流i_1は非常に小さくなり、電流ｉ２が大きくなって、電解電流のほとんどは金属膜ＭＴの表面経由することになる。このため、金属膜ＭＴを構成する銅の電解溶出を効率的に行うことができる。また、電流ｉ２の大きさは、ギャップδｂおよびギャップδｗの大きさによって変化するため、上述したように、コントローラ５５によって研磨工具３のＺ軸方向の位置制御を行ってギャップδｂおよびギャップδｗの大きさを調整することにより、電流ｉ２を一定にすることができる。ギャップδｗの大きさの調整は、電流値信号６２ｓから得られた電解電流、すなわち、電流ｉ２が一定となるように、電流値信号６２ｓをフィードバック信号としてＺ軸サーボモータ１８の制御を行うことで可能である。また、研磨装置１のＺ軸方向の位置決め精度は分解能０．１μｍと十分に高く、加えて、主軸１２ａをウェーハWの主面に対して微小角度で傾斜させていることで実行的な接触面積Ｓは常に一定に維持されることから、電解電流の値を一定に制御すれば、電流密度は常に一定とでき、金属膜の電解溶出量も常に一定にすることができる。

【００４８】以上のように、上記構成の研磨装置１は、上述したウェーハWに形成された金属膜ＭＴを構成する金属を電解液ＥＬによる電解作用よって溶出除去する電解研磨機能を備えている。さらに、上記構成の研磨装置１は、この電解研磨機能に加えて、研磨工具３およびスラリーＳＬによる通常のＣＭＰ装置の化学機械研磨機能も備えており、ウェーハWをこれら電解研磨機能および化学機械研磨の複合作用によって研磨すること（以下、電解複合研磨という）もできる。また、上記構成の研磨装置１は、スラリーＳＬを用いずに研磨工具３の研磨面３ａの機械的な研磨と電解研磨機能との複合作用によって研磨加工を行うこともできる。上記構成の研磨装置１は、電解研磨および化学機械研磨の複合作用によって金属膜を研磨できるため、化学機械研磨のみ、あるいは、機械研磨のみを用いた研磨装置に比べてはるかに高能率に金属膜の除去を行うことができる。金属膜に対する高い研磨レートが得られるため、研磨工具３のウェーハWに対する加工圧力Ｆを化学機械研磨のみ、あるいは機械研磨のみを用いた研磨装置に比べて低く抑えることが可能となり、ディッシング、エロージョンの発生を抑制することができる。

【００４９】以下、本実施形態に係る研磨装置１の電解複合研磨機能を用いた研磨方法について、多層配線構造の半導体装置のデュアルダマシン法による配線形成プロセスに適用した場合を例に説明する。

【００５０】図９は、本発明の半導体装置の製造方法の一実施形態に係る製造プロセスを示す工程図であり、図９に示す工程図に基づいて本実施形態に係る製造プロセスを説明する。まず、図１０に示すように、たとえば、図示しない不純物拡散領域が適宜形成されている、たとえば、シリコン等の半導体からなるウェーハW上に、たとえば、シリコン酸化膜（SiO_2）からなる層間絶縁膜１０２を、たとえば、反応源としてＴＥＯＳ(tetraethylorthosilicate) を用いて減圧ＣＶＤ(Chemical Vapour Deposition)法により形成する。次いで、図１１に示すように、ウェーハの不純物拡散領域に通じるコンタクトホール１０３およびウェーハWの不純物拡散領域と電気的に接続される所定パターンの配線が形成される配線用溝１０４を、たとえば、公知のフォトリソグラフィ技術およびエッチング技術を用いて形成する。なお、配線用溝１０４の深さは、たとえば、８００ｎｍ程度である。

【００５１】次いで、図１２に示すように、バリヤ膜１０５を層間絶縁膜１０２の表面およびコンタクトホール１０３、配線用溝１０４内に形成する。このバリヤ膜３

０５は、たとえば、Ｔａ、Ｔｉ、ＴａＮ、ＴｉＮ等の材料をスパッタリング装置、真空蒸着装置等を用いたＰＶＤ(Physical Vapor Deposition) 法により、たとえば、１５ｎｍ程度の膜厚で形成する。バリヤ膜３０５は、配線を構成する材料が層間絶縁膜１０２中に拡散するのを防止するため、および、層間絶縁膜１０２との密着性を上げるために設けられる。特に、配線材料が銅で層間絶縁膜１０２がシリコン酸化膜のような場合には、銅はシリコン酸化膜への拡散係数が大きく、酸化されやすいため、これを防止する。以上までのプロセスが図９に示すプロセスＰＲ１である。

【００５２】次いで、図１３に示すように、バリヤ膜１０５上に、配線形成材料と同じ材料、たとえば、銅からなるシード膜１０６を公知のスパッタ法により、たとえば、１５０ｎｍ程度の膜厚で形成する（プロセスＰＲ２）。シード膜１０６は、銅を配線用溝およびコンタクトホール内に埋め込んだ際に、銅グレインの成長を促すために形成する。次いで、図１４に示すように、コンタクトホール１０３および配線用溝１０４を埋め込むように、バリヤ膜１０５上に銅からなる金属膜１０７を、たとえば、２０００ｎｍ程度の膜厚で形成する。金属膜１０７は、好ましくは、電解メッキ法または無電解メッキ法によって形成するが、ＣＶＤ法、スパッタ法等によって形成してもよい。なお、シード膜１０６は金属膜１０７と一体化する（プロセスＰＲ３）。

【００５３】ここで、図１５は金属膜１０７をバリヤ膜１０５上に形成した製造プロセス途中の半導体装置の断面の拡大図である。図１５に示すように、金属膜１０７の表面には、コンタクトホール１０３および配線用溝１０４への埋め込みのために、たとえば、６００ｎｍ程度の高さの凹凸が発生している。以上のプロセスは、従来と同様のプロセスで行われるが、本発明の研磨方法では、層間絶縁膜１０２上に存在する余分な金属膜１０７およびバリヤ膜１０５の除去を化学機械研磨ではなく、上記の研磨装置１の電解複合研磨によって行う。また、本発明の研磨方法では、上記の電解複合研磨によるプロセスに先立って、図１６に示すように、金属膜１０７の表面に不動態膜１０８を形成する（プロセスＰＲ４）。この不動態膜１０８は、金属膜１０７を構成する金属（銅）の電解反応を妨げる作用を発揮する材料からなる膜である。

【００５４】不動態膜１０８の形成方法は、たとえば、金属膜１０７の表面に酸化剤を塗布して酸化膜を形成する。金属膜１０７を構成する金属が銅の場合には、酸化銅（ＣｕＯ）が不動態膜１０８となる。また、他の方法として、金属膜１０７の表面に、たとえば、はっ水膜、油膜、酸化防止膜、界面活性剤からなる膜、キレート剤からなる膜、および、シランカップリング剤からなる膜のいずれかを形成して不動態膜１０８とすることも可能である。不動態膜１０８の種類は特に限定されないが、電気抵抗が金属膜１０７に対して高く、機械的強度が比較的低く脆い性質のものを使用する。

【００５５】次に、本発明の研磨方法では、金属膜１０７の凸部に形成された不動態膜１０８のみを選択的に除去する（プロセスＰＲ５）。不動態膜１０８の選択的な除去は、上記の研磨装置１によって行う。なお、使用するスラリーＳＬには、銅に対する研磨レートの高いスラリーを用いる。たとえば、過酸化水素、硝酸鉄、ヨウ素酸カリウム等をベースとした水溶液にアルミナ、シリカ、マンガン系の研磨砥粒を含むものを使用する。まず、ウェーハＷを研磨装置１のウェーハテーブル４２にチャッキングし、電解液ＥＬおよびスラリーＳＬをウェーハＷ上に供給しながら回転する研磨工具３およびスクラブ部材２４をＺ軸方向に下降させてウェーハＷに接触または接近させ、ウェーハＷをＸ軸方向に所定の速度パターンで移動させて研磨加工を行う。また、研磨工具３にマイナス極、電極板２３をプラス極として、研磨工具３と電極板２３との間に直流パルス電圧を印加する。なお、スラリーＳＬのベースとなる水溶液に電解液ＳＬの機能を持たせることにより、スラリーＳＬのみをウェーハＷ上に供給してもよい。

【００５６】ここで、図１７は上記の状態にあるスクラブ部材２４付近における研磨プロセスを示す概念図であり、図１８は研磨工具３付近における研磨プロセスを示す概念図である。図１７に示すように、スクラブ部材２４付近では、回転する電極板２３の溝部２３ｂからスラリーＳＬおよび電解液ＥＬが供給されて、スラリーＳＬおよび電解液ＥＬはスクラブ部材２４を通過してスクラブ部材２４の全面からウェーハＷ上に供給される。金属膜１０７上に形成された不動態膜１０８は、電解液ＥＬによる電解作用を受けないため電解液ＥＬ中への金属膜１０７を構成する銅の溶出は抑制された状態にある。このため、金属膜１０７には電流がほとんど流れず、上記の電流計６２のモニタした電流値は、低く安定したままである。図２５は、本実施形態の電解複合研磨プロセスにおいて電流計６２でモニターした電流値の一例を示すグラフである。図２５に示す電流値の開始位置付近が上記の状態である。

【００５７】スクラブ部材２４の回転にしたがって、機械的除去作用あるいはスラリーＳＬに含まれる、たとえば、酸化アルミニウムからなる研磨砥粒ＰＴの機械的除去作用によって不動態膜１０８の高い部分、すなわち、金属膜１０７の凸部上の不動態膜１０８から機械的に除去されていく。一方、図１８に示すように、研磨工具３付近では、研磨工具３の機械的除去作用、あるいは、研磨砥粒ＰＴの機械的除去作用によって金属膜１０８に存在する不動態膜１０８が高い部分から除去される。

【００５８】このようにして、たとえば、図１９に示すように、金属膜１０７の凸部上に形成された不動態膜１０８が選択的に除去されると、不動態膜１０８が選択的

に除去された部分から金属膜１０７が表面に露出する。

【００５９】金属膜１０７が表面に露出すると、凸部である金属膜１０７の露出部分が選択的に溶出する（プロセスＰＲ５）。このときの電解液ＥＬの作用は、図１８に示すように、不動態膜１０８が除去された部分である金属膜１０７の凸部は、金属膜１０７を構成する銅が電解作用によって銅イオンＣｕ＋として電解液ＥＬ中に溶出する。これによって、金属膜１０７中にはマイナス電子ｅ－が流れ、このマイナス電子ｅ－は、図１７に示したように、金属膜１０７の表面から電解液ＥＬを通って電極板２３に流れ、上記した電流i_2となる。

【００６０】上述したように、金属膜１０７を構成する銅は、不働態膜１０８に比べて電気抵抗が低く電流密度が増すため、集中的な電解作用を受け選択的に溶出がおこり、材料除去が加速される。また、電解液ＥＬを介して通電するため、陽極としての金属膜１０７と陰極としての研磨工具３の電位差が一定の場合、極間距離が短い、すなわち、電気抵抗値が低いほうが極間に流れる電流値は大きくなる。このため、陰極としての研磨工具３に対して、陰極としての金属膜１０７の凹凸による電極間距離の差（金属膜１０７の凸部のなかでも高い部分のほうが極間距離が短く電気抵抗が低い）があれば、電流密度の違いから高い順に溶出速度が大きくなる効率的な平坦化が進行する。このとき、図２５において、Ｐ１で示すように、上記の電流計６２のモニタした電流値は上昇しはじめる。このような作用によって、金属膜１０７の凸部は、機械的平坦化に比べて、はるかに高能率に平坦化が行われる。

【００６１】上記の作用によって、金属膜１０７の凸部がほぼ完全に平坦化されるまで選択的な電解複合研磨が完了した金属膜１０７の表面は、たとえば、図２０に示すように、金属膜１０７の凹部であった部分に残存する不働態膜１０８と金属膜１０７の凸部が除去された銅の新生面の複合面になる。

【００６２】続いて、図２１に示すように、この金属膜１０７の表面に研磨工具３およびスラリーＳＬ中の研磨砥粒ＰＴにより行われる機械的除去と電解液ＥＬによる電解作用が複合した電解複合研磨が進行する（プロセスＰＲ７）。このとき、残存する不働態膜１０８の機械的強度は上述したように銅の新生面に比べて低いため、不働態膜１０８が電解複合研磨されるとき、主に機械的作用により除去され、その下にある銅表面が露出し、その面積に比例して電解作用が増大する。不働態膜１０８が完全除去された時点で金属膜１０７を構成する銅の表面積は最大となる。これと同時に、電流計６２でモニターした電流は、図２５においてＰ１の位置から上昇した電流値は、不働態膜１０８の除去に伴って上昇した後、銅の表面積が最大となるＰ２で示す時点で最大値となる。ここまでのプロセスによって、金属膜１０７の表面の初期凹凸の平坦化は完了する。

【００６３】このように、本実施形態の電解複合研磨は、電気化学的に研磨レートをアシストされた研磨であるため、通常の化学機械研磨に比べて低い加工圧力で研磨を行うことができる。このことは、単純な機械的研磨として比較してもスクラッチの低減、段差緩和性能、ディッシングやエロージョンの低減などの面で非常に有利である。さらに、低い加工圧力で研磨を行うことができるため、機械強度が低く通常の化学機械研磨では破壊されてしまい易い、有機系の低誘電率膜や多孔質低誘電率絶縁膜を層間絶縁膜１０２に用いてた場合に非常に有利である。

【００６４】上記の金属膜１０７の電解複合研磨が進行して、余分な金属膜１０７が除去されると、図２２に示すように、バリア膜１０５が露出する（プロセスＰ８）。このとき、電流計６２のモニターする電流は、図２５のＰ２で示す金属膜１０７上の不働態膜１０８がすべて除去された時点より最大値をとり、図２５のＰ３で示すバリア膜１０５が露出する時点まで略一定の値をとる。バリア膜１０５が露出すると、たとえば、Ｔａ、Ｔｉ、ＴａＮ、ＴｉＮ等の材料を使用した場合には、その電気抵抗が銅に比べ大きいため、たとえば、図２５のバリア膜１０５の露出が開始するＰ３で示す時点から電流計６２でモニターした電流値が低下しはじめる。この状態では、金属膜１０７の不均一分の銅膜が残留する状態であり、この状態で研磨加工を一旦停止する。この研磨加工の停止は、図２５のＰ４で示すように電流値が所定の値まで下がったことをコントローラ５５が判断し、研磨装置１の研磨動作を停止させる。

【００６５】次いで、バリア膜１０５を除去する（プロセスＰＲ９）。このバリア膜１０５を除去するプロセスでは、上記の銅から構成される金属膜１０７に対して研磨レートの高いスラリーＳＬではなく、Ｔａ、ＴａＮ、Ｔｉ、ＴｉＮ等の材料から形成されたバリア膜１０５に対して研磨レートが高く、金属膜１０７に対して研磨レートの低いスラリーＳＬを使用する。すなわち、バリア膜１０５と金属膜１０７の研磨レートの選択比ができるだけ大きなスラリーＳＬを使用する。

【００６６】さらに、オーバーポリッシュによるディッシング、エロージョンの発生を抑制する観点等から、電解電源６１の出力電圧を上記のプロセスよりも小さくしてバリア膜１０５の研磨除去を行う。また、研磨工具３の加工圧力も上記のプロセスよりも小さくするのが好ましい。また、電解電源６１の出力電圧を小さくすること、および、バリア膜１０５を除去すると層間絶縁膜１０２が表面に露出することから、電解電流の値は小さくなるので、上記の電流計６２による電解電流のモニタに代えて、上記の抵抗計６３によってスクラブ部材２４と研磨工具３との間に電気抵抗をモニターする。

【００６７】バリア膜１０５を除去すると、図２３に示すように、層間絶縁膜１０２が表面に露出する（プロセ

スＰ１０）。層間絶縁膜１０２が露出すると、図２３に示すように、この露出部分には、陽極として表面に通電するための金属膜１０７やバリア膜１０５がないため、スクラブ部材２４による通電が遮断され、層間絶縁膜１０２の露出部分での電解作用が停止する。このとき、抵抗計６３によってモニターした電気抵抗値は増加しはじめる。

【００６８】ここで、金属膜１０７の残存する部分とバリア膜１０５の露出部分との間で、上記した金属膜１０７の凸部の段差緩和の場合と同様に、すなわち、不働態膜１０８の代りにバリア膜１０５を電気抵抗の高い部分として、金属膜１０７の残存部分への電流密度の集中がおこり選択的に金属膜１０７の残存部分は溶出除去される。電解作用の停止した部分には、研磨工具３とスラリーＳＬによる機械的な材料除去作用のみが主体的に働く。

【００６９】ところで、通常の化学機械研磨では、バリア膜１０５および金属膜１０７の層間絶縁膜１０２に対する研磨レート選択比をできるだけ大きくし、そのレート差をマージンとして層間絶縁膜１０２の上面の寸法精度を確保しようとしている。このため、金属膜１０７のディッシングは避けられない構成となっている。また、選択比を低く設定すればディッシングはある程度少なくすることができるが、寸法精度は、ウェーハ面内除去量分布の均一性に依存するため、バリア膜１０５および金属膜１０７の除去が十分ではない場合も発生する。このため、バリア膜１０５および金属膜１０７が層間絶縁膜１０２の上面に残存した状態であるアンダーポリッシュを防ぐためには、除去量の面内不均一分のオーバーポリッシュが必要となり、このオーバーポリッシュによるエロージョンの悪化は本質的に避けられない。一方、本実施形態では、ウェーハＷの面内均一性をある程度確保しておけば、層間絶縁膜１０２上に残るバリア膜１０５、あるいは、金属膜１０７の残存部分には電解作用が働くことで高能率除去され、層間絶縁膜１０２の露出部分から溶出が停止する。このため、層間絶縁膜１０２の寸法精度は自動的に確保され、ディッシング、エロージョンの発生が抑制される。

【００７０】上記のようにして、たとえば、Ｔａ、ＴａＮ、Ｔｉ、ＴｉＮ等の材料から形成されたバリア膜１０５を完全に除去することができるとともに、オーバーポリッシュによるディッシング、エロージョンの発生を抑制することができる。また、上述したバリア膜１０５の除去プロセスでは、絶対電流値は低く、機械的負荷も軽く設定することで除去速度は遅くなるが、残存する膜厚が不均一な部分の残留分の銅膜からなる金属膜１０７が少なければ、バリア膜１０５は金属膜１０７に比べて薄いためバリア膜１０５の除去量自体は小さく、このプロセスにおいてバラツキ・不均一があったとしてもディッシング、エロージョンの絶対値は無視できる程度に少なくでき、処理時間も短くすることができる。さらに、本実施形態に係る研磨方法は、機械的研磨に加えて電気化学的作用が付加された複合加工であるため、平坦化した表面はダメージが少なく機械的にも平滑な面を得ることができる。

【００７１】次いで、抵抗計６３でモニターした電気抵抗値に基づいて、電気抵抗値が最大値すなわち配線形成が完了した時点でバリア膜１０５を除去するプロセスを終了する（プロセスＰＲ１１）。コントローラ５５は電気抵抗値の値を判断して、研磨装置１の加工動作を停止させる。なお、研磨加工を終了する前に、電解作用を付加したままの状態で、研磨工具３をウェーハＷの表面に接触させず、例えば、１００μｍ程度上を通過させることで、機械的研磨は行わず、電解作用のみによるダメージフリーの表面を形成することができる。これにより、図２３に示すように、層間絶縁膜１０２中には配線１０９およびコンタクト１１０が最終的に形成される。

【００７２】次いで、配線１０９およびコンタクト１１０が形成された半導体装置に対してフラッシングを行う（プロセスＰＲ１２）。このフラッシングプロセスは、配線１０９およびコンタクト１１０が形成された後、直ぐに洗浄薬液、酸化防止剤をウェーハＷの表面に供給しながら、ウェーハＷには通電せず、図２４に示すように、研磨工具３にプラスのパルス電圧を印加し、純水洗浄、薬液洗浄を行い、ウェーハＷの表面に存在するスラリーＳＬやパーティクルを除去する。本実施形態では、フラッシングを行う以前にも、スラリーＳＬに含まれる、たとえば、アルミナからなる研磨砥粒ＰＴは分散性をよくするために正に帯電させているため、銅からなる金属膜１０７表面に機械的に衝突して除去加工に寄与したのち摩滅せずに残留した場合にも、陽極としての金属膜１０７を構成する銅の表面に埋没することはなく、図２３に示したように、陰極としての研磨工具３の表面に再付着して次の加工に寄与する。さらに、正に帯電したパーティクルも陰極としての研磨工具３の表面に引き寄せられるため、銅の表面に埋没することはない。一方、ウェーハＷの表面に残存して負に帯電しているパーティクルも上記のフラッシングによって、ウェーハＷの表面から除去することができる。また、研磨砥粒ＰＴが負に帯電したスラリーＳＬを使用した場合にも同様に除去できる。配線形成材料が銅である場合、酸化されやすく、銅表面を変質させずに、金属イオンやパーィクルを除去する必要があるが、本実施形態では、予め研磨砥粒ＰＴを正に帯電させておき、かつ、フラッシングによってこの問題が解消される。なお、研磨砥粒として、酸化アルミニウム（アルミナ）を例として挙げたが、酸化セリウム、シリカ、酸化ゲルマニウムなどを使用した場合にも同様である。

【００７３】以上のように、本実施形態に係る半導体装置の製造方法によれば、絶縁膜１０２内に形成した配線

用溝配線およびコンタクトホールを埋め込む金属膜１０７に不動態膜１０８を形成し、金属膜１０７の凸部に形成された不動態膜１０８を選択的に除去し、残った不動態膜１０８をマスクとして表面に露出した金属膜１０７を電解研磨によって選択的に除去し、かつ電流密度に集中によって集中的に除去することで、通常のＣＭＰに比べてはるかに高能率に初期凹凸を平坦化することができる。また、初期凹凸が平坦化された金属膜１０７は、電解研磨と化学機械研磨の複合した電解複合研磨によって除去されるため、通常のＣＭＰに比べてはるかに高能率に余分な金属膜１０７を除去できる。このため、研磨工具３の加工圧力を低く設定しても十分な研磨レートが得られ、金属膜１０７へのダメージを軽減できるとともに、ディッシングやエロージョンの発生を抑制することができる。

【００７４】また、本実施形態に係る半導体装置の製造方法によれば、余分な金属膜１０７を除去してバリヤ膜１０５が露出した時点で、研磨を停止し、スラリーＳＬをバリヤ膜１０５に対して研磨レートの高いものに変更し、電解電源６１の出力電圧等の研磨条件を変更して余分なバリヤ膜１０５を除去を行うため、余分なバリヤ膜１０５を確実に除去でき、オーバポリッシュが必要な場合にも、ディッシングやエロージョンの発生量を小さく抑えることができる。

【００７５】また、本実施形態に係る半導体装置の製造方法によれば、金属膜の研磨を電解複合研磨によって高能率に行うため、研磨工具３の加工圧力を低圧力にすることができるため、たとえば、低消費電力化および高速化等の観点から誘電率を低減するために層間絶縁膜１０２として機械的強度が比較的低い有機系低誘電率膜や多孔質低誘電率絶縁膜を使用した場合にも、これらの絶縁膜へのダメージを低減することができる。

【００７６】上述した実施形態では、金属膜の研磨加工量の絶対値は、電解電流の積算量と研磨工具３のウェーハＷを通過する時間で制御できる。上述した実施形態では、銅による配線形成プロセスの場合を説明したが、本発明はこれに限定されることなく、タングステン、アルミニウム、銀等の種々の金属配線形成プロセスに適用可能である。

【００７７】また、上述した実施形態では、スラリーＳＬを用いた化学機械研磨と電解液ＥＬを用いた電解研磨とを複合した電解複合研磨の場合について説明したが、本発明はこれに限定されない。すなわち、本発明は、スラリーＳＬを用いずに、電解液ＥＬの電解研磨と研磨工具３の研磨面３ａによる機械研磨によって電解複合研磨を行うことも可能である。

【００７８】また、上述した実施形態では、研磨工具３と電極板２３との間を流れる電流値をモニターし、この値に基づいてバリヤ膜１０５が露出するまでの研磨プロセスを管理したが、全ての研磨プロセスをモニターした電流値で管理することも可能である。同様に、上述した実施形態では、研磨工具３と電極板２３との間の電気抵抗値をモニターし、この値に基づいて、バリヤ膜１０５の除去プロセスのみの管理を行う構成としたが、全ての研磨プロセスをモニターした電気抵抗値で管理することも可能である。

【００７９】<u>変形例１</u>

図２６は、本発明に係る研磨装置の一変形例を示す概略図である。上述した実施形態に係る研磨装置１では、ウェーハＷ表面への通電を、導電性の研磨工具と、スクラブ部材２４を備えた通電板２３とによって行った。図２６に示すように、ホイール状の研磨工具４０１は、研磨装置１の場合と同様に導電性を持たせるとともに、ウェーハＷをチャッキングし回転させるウェーハテーブル４０２にも導電性を持たせる構成としてもよい。研磨工具４０１への給電は、上述した実施形態と同様の構成で行う。この場合には、ウェーハテーブル４０２への通電は、ウェーハテーブル４０２の下部にロータリージョイント４０３を設け、ロータリージョイント４０３によって回転するウェーハテーブル４０２への通電を常に維持する構成とすることで、電解電流の供給を行うことができる。

【００８０】<u>変形例２</u>

図２７は、本発明に係る研磨装置の他の変形例を示す概略図である。ウェーハＷをチャッキングし、回転させるウェーハテーブル５０２は、ウェーハＷをウェーハＷの周囲に設けたリテーナリング５０４によって保持している。研磨工具５０１には、導電性を持たせるとともに、リテーナリング５０４にも導電性を持たせ、研磨工具５０１には上述した実施形態と同様の構成で給電する。また、リテーナリング５０４は、ウェーハＷに形成された上記のバリア層部分まで覆い通電する。さらに、リテーナリング５０４には、ウェーハテーブル５０２の下部に設けられたロータリジョイント５０３を通じて給電する。なお、研磨工具５０１がウェーハＷに接触しても、エッジの部分でリテーナリング５０４の厚さ以上の隙間が維持できるように研磨工具３の傾斜量を大きくしておくことで、研磨工具５０１とリテーナリング５０４との干渉を防ぐことができる。

【００８１】<u>変形例３</u>

図２８は、本発明に係る研磨装置の他の実施形態を示す概略構成図である。図２８に示す研磨装置は、従来型のＣＭＰ装置に本発明の電解研磨機能を付加したものであって、定盤２０１上に研磨パッド（研磨布）２０２が貼着された研磨工具の研磨面にウェーハチャック２０７によってチャッキングされたウェーハＷの全面を回転させながら接触させてウェーハＷの表面を平坦化する研磨装置である。研磨パッド２０２には、陽極電極２０４と陰極電極２０３とが放射状に交互に配置されている。また、陽極電極２０４と陰極電極２０３とは絶縁体２０６

によって電気的に絶縁されており、陽極電極２０４と陰極電極２０３は、定盤２０１側から通電される。これら陽極電極２０４と陰極電極２０３と絶縁体２０６とによって研磨パッド２０２は構成されている。また、ウェーハチャック２０７は、絶縁材料から形成されている。さらに、この研磨装置には、研磨パッド２０２の表面に電解液ＥＬおよびスラリーＳＬを供給する供給部２０８が設けられており、電解研磨および化学機械研磨を複合させた電解複合研磨が可能になっている。

【００８２】ここで、図２９は、上記構成の研磨装置による電解複合研磨動作を説明するための図である。なお、ウェーハW表面には、たとえば、銅膜２１０が形成されているものとする。図２９に示すように、電解複合研磨中には、ウェーハW表面に形成された銅膜２１０と研磨パッド２０２の研磨面との間には、電解液ＥＬおよびスラリーＳＬが介在した状態で、陽極電極２０４と陰極電極２０３との間に直流電圧が印加され、電流ｉが陽極電極２０４から電解液ＥＬを通って銅膜２１０内を伝って再び電解液ＥＬを通って陰極電極２０３に流れる。このとき、図２９に示す円G内の付近では、電解作用によって銅膜２１０が溶出するとともに、銅膜２１０は研磨パッド２０２とスラリーＳＬによる機械的除去作用によってさらに除去される。

【００８３】このような構成とすることにより、上述した実施形態に係る研磨装置１と同様の効果が奏される。なお、研磨パッドに設ける陽極電極、陰極電極の配置は図２８の構成に限定されるわけではなく、たとえば、図３０に示すように、線状の複数の陽極電極２２２を縦横に等間隔に配列し、陽極電極２２２によって囲まれる各矩形領域に陰極電極２２３を配置し、陽極電極２２２と陰極電極２２３とを絶縁体２２４で電気的に絶縁した研磨パッド２２１としてもよい。さらに、たとえば、図３１に示すように、半径がそれぞれ異なる環状の陽極電極２４２を同心上に配置し、各陽極電極２４２間に形成される環状領域に陰極電極２４３をそれぞれ配置し、陽極電極２４２と陰極電極２４３とを絶縁体２４４で電気的に絶縁した研磨パッド２４１としてもよい。

【００８４】

【発明の効果】本発明によれば、機械研磨と電解研磨との複合作用によって金属膜を研磨するので、機械研磨による金属膜の平坦化の場合に比べて、非常に高能率に金属膜の凸部の選択的除去および平坦化が可能となる。また、本発明によれば、研磨工具を陰極として通電するため、予め正に帯電したパーティクルや研磨剤中の研磨砥粒が研磨工具に引き寄せられ、ウェーハ表面へ残留するのを防止することができ、歩留りの向上を図ることができる。また、本発明によれば、高能率に金属膜の除去が可能となるので、比較的低い研磨圧力でも十分な研磨レートが得られ、研磨した金属膜にスクラッチ、ディッシング、エロージョン等が発生するのを抑制することができる。さらに、本発明によれば、比較的低い研磨圧力でも十分な研磨レートが得られため、半導体装置の低消費電力化および高速化等の観点から誘電率を低減するために層間絶縁膜として機械的強度が比較的低い有機系低誘電率膜や多孔質低誘電率絶縁膜を使用した場合にも、容易に適用可能である。また、本発明によれば、層間絶縁膜上に残るバリヤ膜、あるいは、金属の部分は電解作用が働くことで効率的に除去され、絶縁膜の露出部分から溶出が停止するため、研磨の停止精度を自動的に確保することができ、ディッシング、エロージョンを抑制することができる。また、本発明によれば、電解電流をモニタリングすることで、研磨プロセスの管理を行うことができ、研磨プロセスの進行状態を正確に把握することが可能となる。また、本発明によれば、研磨工具と電極部材との間の電気抵抗値をモニタリングすることで、電流が流れにくい、または電流が流れない膜と金属膜とを同時に研磨するような場合でも、研磨プロセスを正確に管理することができる。

【図面の簡単な説明】

【図１】本発明の研磨装置の一実施形態の構成を示す図である。

【図２】図１の研磨装置のヘッド部の詳細を示す拡大図である。

【図３】（ａ）は電極板２３の構造の一例を示す下面図であり、（ｂ）は電極板２３と、通電軸２０、スクラブ部材２４および絶縁部材４との位置関係を示す断面図である。

【図４】研磨工具とウェーハとの関係を示す図である。

【図５】研磨工具に対してウェーハをX軸方向に移動させた様子を示す図である。

【図６】ヘッド加工部でウェーハを研磨加工する状態を示す概略図である。

【図７】研磨工具と電極板との関係を示す図である。

【図８】本発明の研磨装置の電解研磨機能を説明するための図である。

【図９】本発明の半導体装置の製造方法の一実施形態に係る製造プロセスを示す工程図である。

【図１０】本発明の半導体装置の製造方法の製造プロセスを示す断面図である。

【図１１】図１０に続く製造プロセスを示す断面図である。

【図１２】図１１に続く製造プロセスを示す断面図である。

【図１３】図１２に続く製造プロセスを示す断面図である。

【図１４】図１３に続く製造プロセスを示す断面図である。

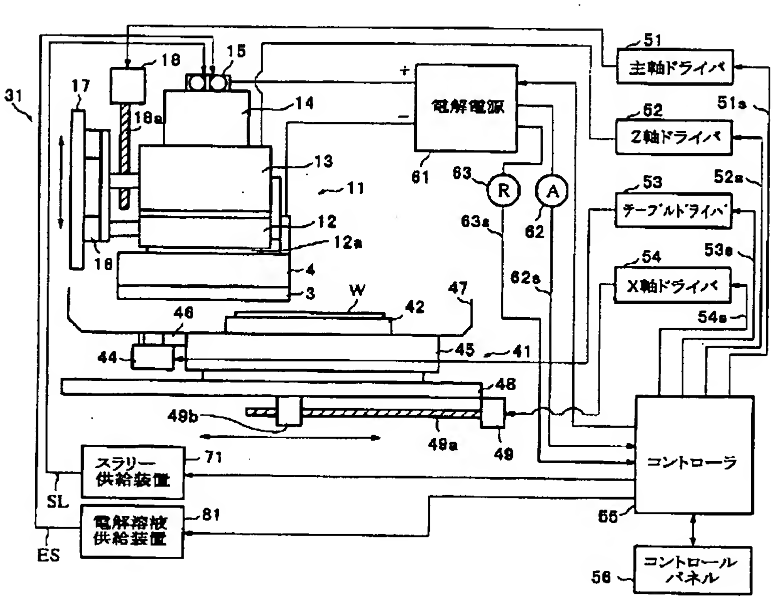
【図１５】図１４に示す半導体装置の断面構造の拡大図である。

【図１６】図１４に続く製造プロセスを示す断面図であ

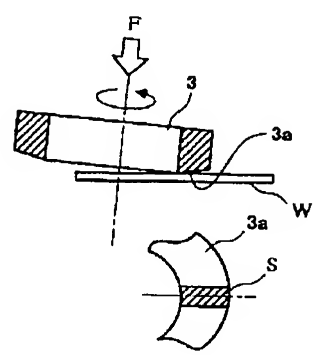
る。
【図１７】スクラブ部材２４付近における研磨プロセスを示す概念図である。
【図１８】研磨工具３付近における研磨プロセスを示す概念図である。
【図１９】図１６に続く製造プロセスを示す断面図である。
【図２０】金属膜の凸部が選択的に除去され平坦化された状態を示す断面図である。
【図２１】図１９に続く製造プロセスを示す断面図である。
【図２２】図２１に続く製造プロセスを示す断面図である。
【図２３】図２２に続く製造プロセスを示す断面図である。
【図２４】研磨加工が終了した半導体装置に対してフラッシングをした状態を示す断面図である。
【図２５】電解複合研磨プロセスにおいてモニターした電流値の一例を示すグラフである。
【図２６】本発明の研磨装置の変形例を示す図である。
【図２７】本発明の研磨装置のさらに他の変形例を示す図である。
【図２８】本発明に係る研磨装置の他の実施形態を示す概略構成図である。
【図２９】図２８に示した研磨装置による電解複合研磨動作を説明するための図である。
【図３０】研磨パッドの電極構成の他の例を示す図であ＊

＊る。
【図３１】研磨パッドの電極構成のさらに他の例を示す図である。
【図３２】デュアルダマシン法による配線形成プロセスを示す断面図である。
【図３３】図３２に続く配線形成プロセスを示す断面図である。
【図３４】図３３に続く配線形成プロセスを示す断面図である。
【図３５】図３４に続く配線形成プロセスを示す断面図である。
【図３６】図３５に続く配線形成プロセスを示す断面図である。
【図３７】図３６に続く配線形成プロセスを示す断面図である。
【図３８】ＣＭＰ法による金属膜に研磨加工において発生するディッシングを説明するための断面図である。
【図３９】ＣＭＰ法による金属膜に研磨加工において発生するエロージョンを説明するための断面図である。
【図４０】ＣＭＰ法による金属膜に研磨加工において発生するリセスを説明するための断面図である。
【図４１】ＣＭＰ法による金属膜に研磨加工において発生する
【符号の説明】
１…研磨装置、１１…加工ヘッド部、６１…電解電源、５５…コントローラ５５、７１…スラリー供給装置、８１…電解液供給装置。

【図１】



【図４】



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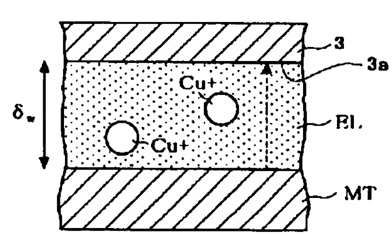
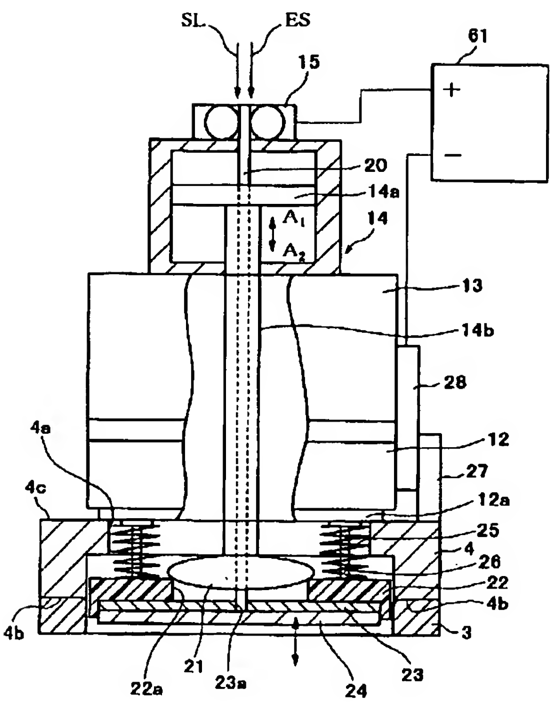
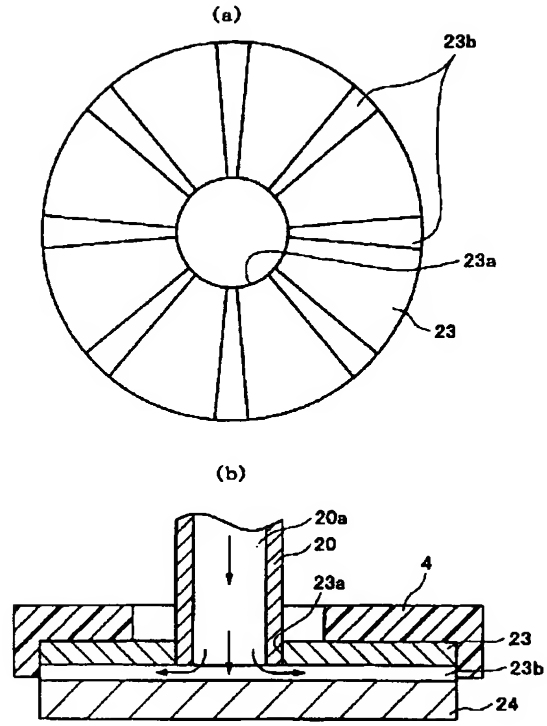


【図２】



【図３】



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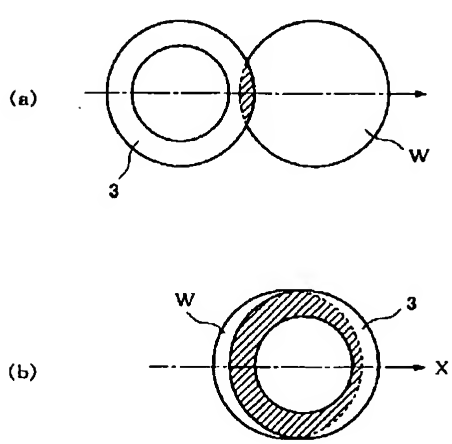

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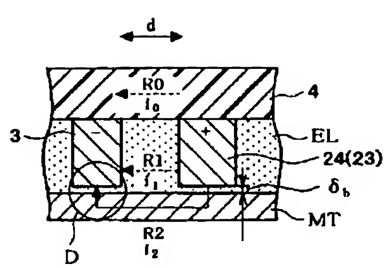
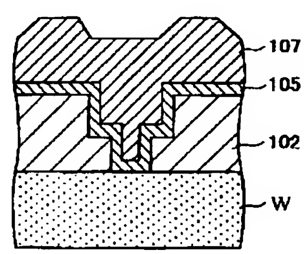
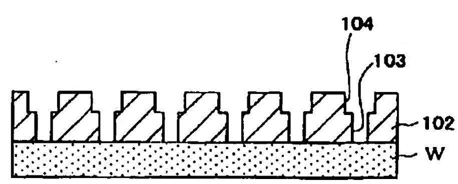


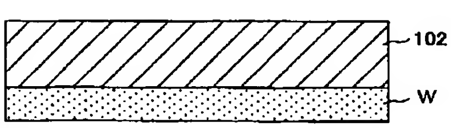
【図１５】



【図１１】



【図１０】



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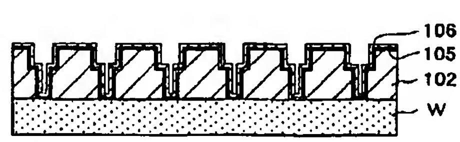

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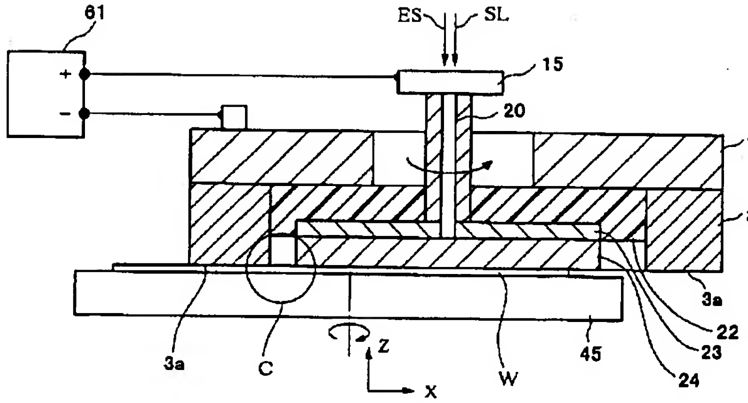

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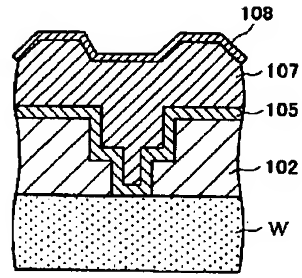

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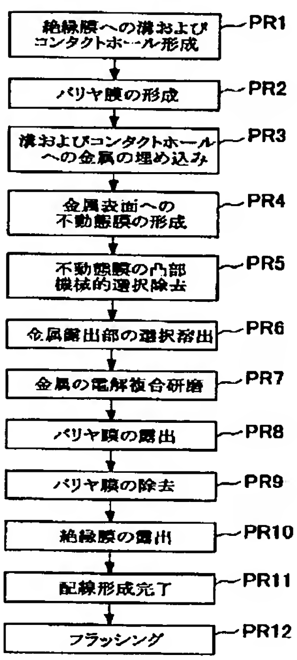
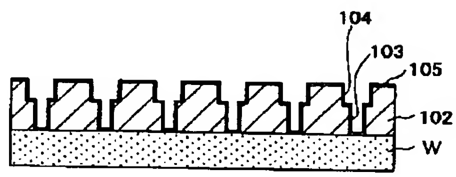


【図１２】



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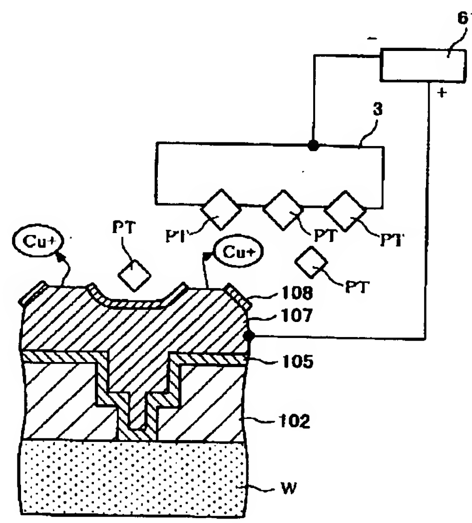

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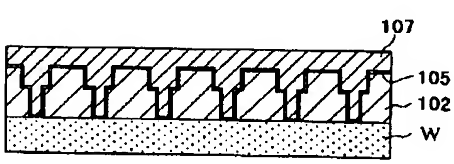

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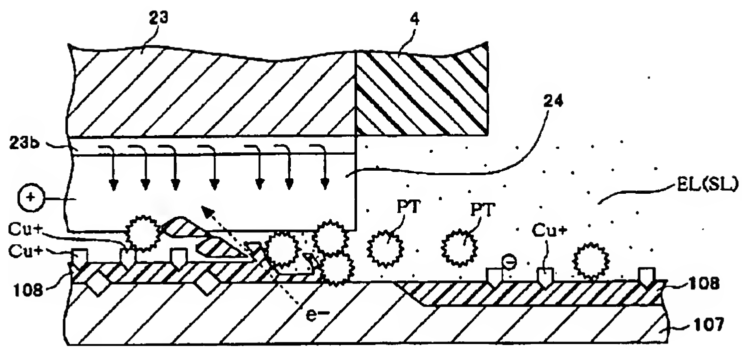
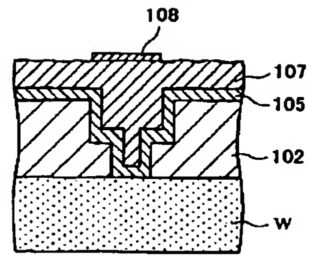
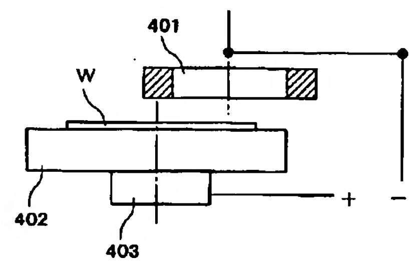


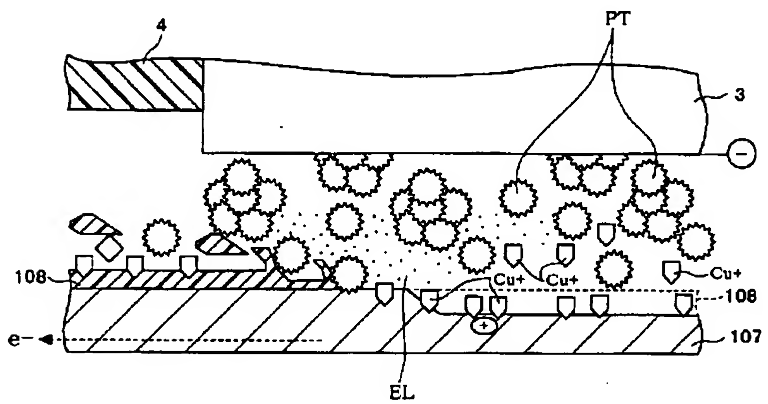
【図２０】



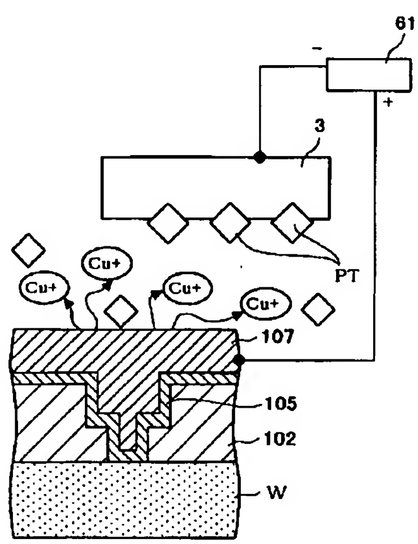
【図２６】



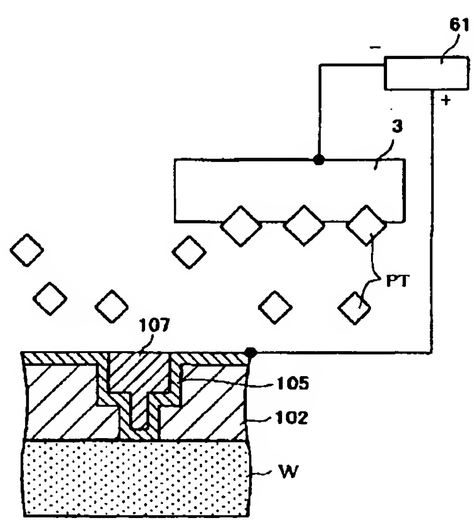
【図１８】



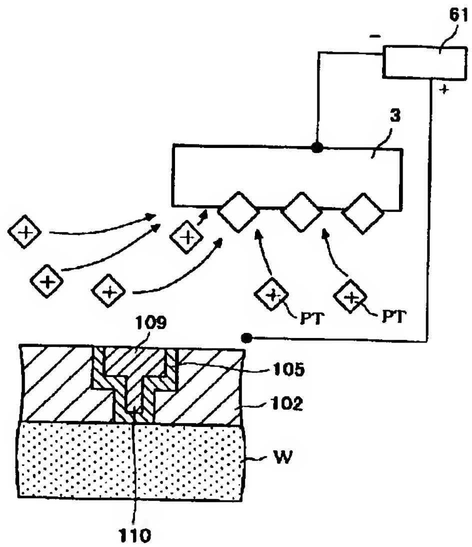
【図２１】



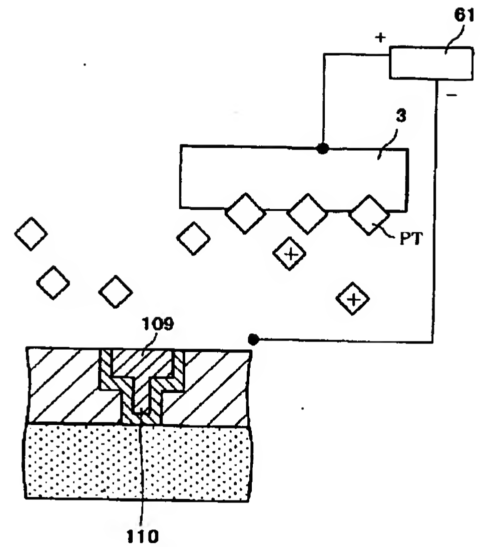
【図２２】



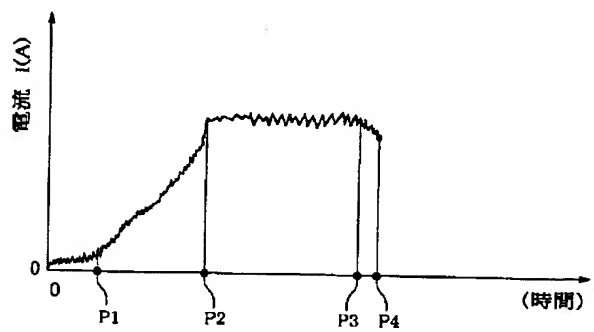
【図２３】



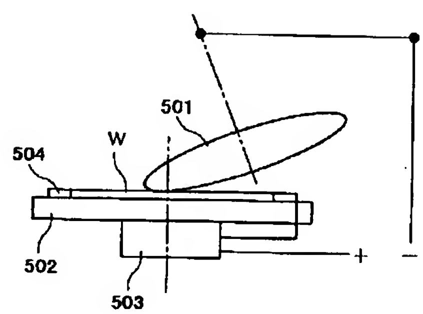
【図２４】



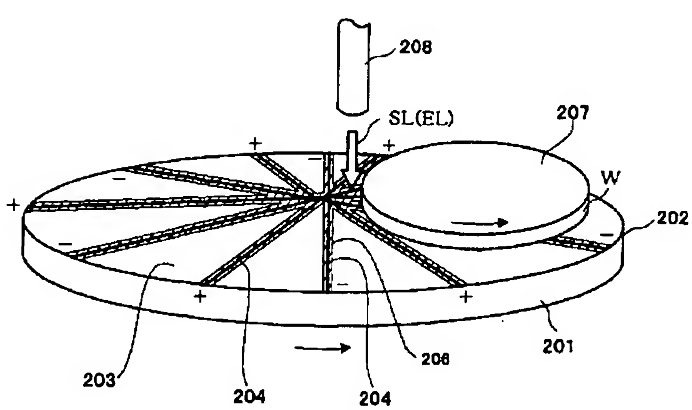
【図２５】



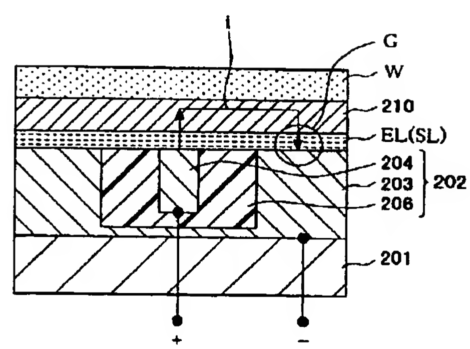
【図２７】



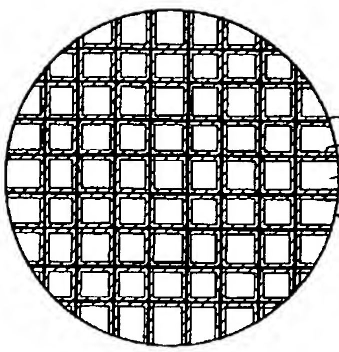
【図２８】



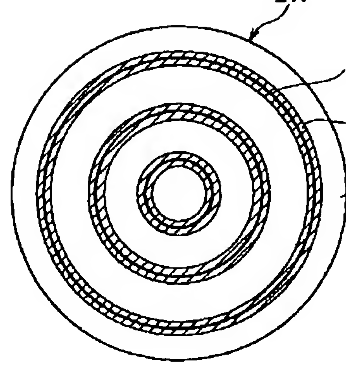
【図２９】



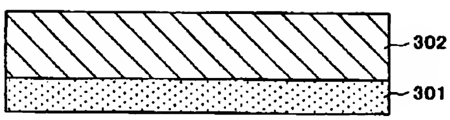
【図３０】



【図３１】



【図３２】



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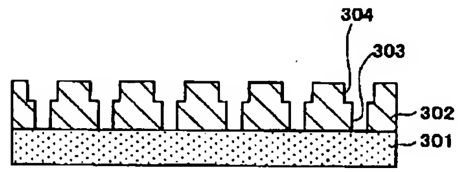

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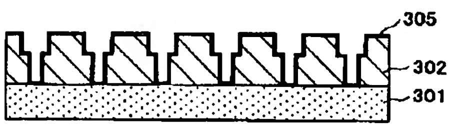

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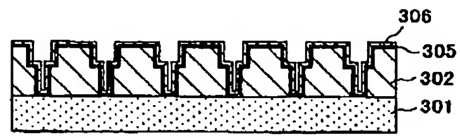

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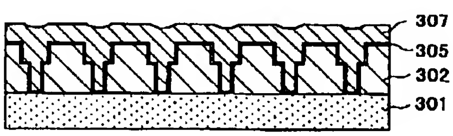

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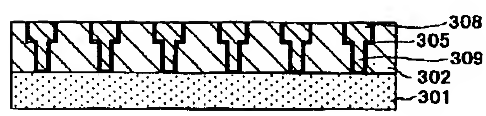

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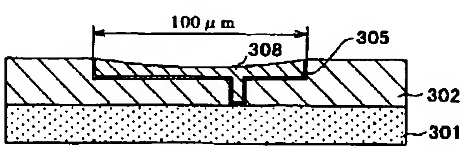

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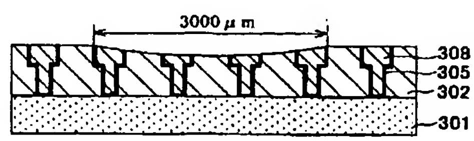

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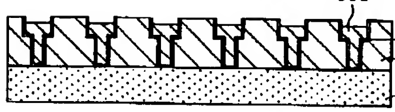

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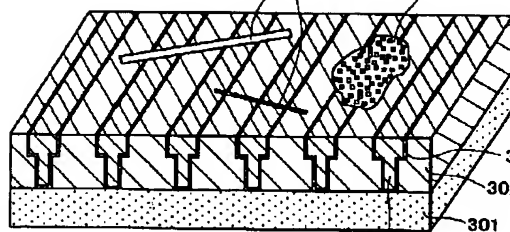

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